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OF CAMBRIDGE,

(Class of 1858.)

Through his Mother,

CATHARINE AMELIA BARTLETT.

3 February, 1865.

Wm. P. G. Bartlett.
Boston, U.S.

THE COMETS.

THE COMETS:

A DESCRIPTIVE TREATISE UPON THOSE BODIES.

WITH

A CONDENSED ACCOUNT

OF

THE NUMEROUS MODERN DISCOVERIES

RESPECTING THEM;

AND

A TABLE OF ALL THE CALCULATED COMETS,

From the Earliest Ages to the Present Time.

BY

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PREFACE.

There is perhaps no branch of astronomy in which our knowledge has progressed more rapidly of late years than that relating to the Comets, but I believe there is not at present any special descriptive work upon the subject. In treatises on the science of astronomy generally, the space allotted to the Comets is usually very limited, and many interesting points connected with their history are necessarily passed over unnoticed. I have endeavoured, in the following pages, to supply the want of an elementary treatise upon these bodies, and to place before the reader a popular account of the discoveries which have been made in the cometary department of astronomy in modern times, and a brief description of the most remarkable comets recorded in history.

The facts which are here collected together are, for the most part, scattered through many works of a purely scientific character, usually in foreign languages, and not known or easily accessible to the general reader. The Catalogue of the elements of the Orbits of Comets, with the accompanying Notes, will, it is hoped, be acceptable to the young student, as presenting in a small compass the results of a vast amount of time and labour which various astronomers have expended upon them.

J. RUSSELL HIND.

Grove-road, St. John's Wood, London,
November, 1852.

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THE COMETS.

CHAPTER I.

OF COMETS IN GENERAL—THEIR NUMBER—DURATION OF VISIBILITY—LENGTH OF THEIR APPARENT TRACKS IN THE HEAVENS—THEIR NUCLEI AND TAILS—APPARENT DIMENSIONS.

COMETS are nebulous-looking bodies, moving in orbits of great eccentricity, and visible to us only about the time of their nearest approach to the sun, or, as it is termed by astronomers, the time of perihelion passage. Unlike the planets, they move in every possible direction, and are seen as well near the poles as about the equatorial or zodiacal regions of the heavens.

In the dark ages of superstition and ignorance, these bodies were regarded as omens of evil to men in general, and the sudden appearance of a great comet excited the utmost consternation, and on more than one occasion influenced the progress of sublunary affairs. One which became visible in the spring of 837 in the southern parts of the heavens, so alarmed Louis I. of France, that he ordered the building of churches and monasteries, in the hope of appeasing the

wrath of heaven, which was considered to be manifested by its appearance. Again, in June, 1456, when the successes of the Turks under Mahomet II. excited the utmost fear at Rome for the safety of Christendom, a great comet (known at the present day as Halley's) was observed, and the Pope, Calixtus III., regarding it as a sign of approaching evils, caused prayers to be said in the churches, and the bells to be rung every day at noon, as a warning to the inhabitants to supplicate the divine aid and forgiveness. Those who neglected this call were subject to severe punishment. Hence arose the custom, still prevalent in Roman Catholic countries, of ringing the cathedral bells at noon. A century later, or in 1556, the appearance of a fine comet is said to have induced Charles V. of Austria to cede the imperial crown to his son Ferdinand. The historians of these ages, in speaking of comets, frequently describe them as of 'horrible aspect,' or as celestial monsters of prodigious magnitude, fearful and terrible stars. While they were beheld with such feelings of dread and superstition, it will hardly be expected that many useful accounts of their movements amongst the stars would be transmitted to us, and it accordingly happens that but very little information available to astronomers at the present day, is to be found in European chronicles. The Chinese astronomers, though they looked upon comets without any fears of their malignant agencies, had a very fanciful opinion respecting them, which nevertheless led to the frequent observation of the position of these bodies in the heavens, the results of which have been found most valuable in modern times.

The number of comets from the Christian era to the middle of the present century, of which there is any trustworthy record, is rather over 600, including, besides the comets mentioned by European historians, all those observed in China, according to the annals of the various dynasties reigning in that country. But as the telescope was not much employed in searching out these objects before the middle of the eighteenth century, the real number of comets which have visited these parts of space must be very much larger, probably amounting to not less than 3000, since it would appear, from the experience of the past century, that only one in every five becomes sufficiently conspicuous to the naked eye to attract general attention. The Chinese, it is true, were very diligent in their celestial observations, yet many comets must have escaped their notice, since they had no telescopes to assist them. A considerable number of comets have doubtless appeared in past times in the southern heavens only, so as to be invisible in Europe, and allowing for this, we shall probably be within reasonable limits when we assume that upwards of 4000 have approached the sun within the orbit of Mars since the commencement of the Christian era.

The following table exhibits the number of sufficiently authenticated comets in each century:—

Century.	Comets observed in Europe and China.	Century.	Comets observed in Europe and China.
I.	22	VI.	25
II.	23	VII.	22
III.	44	VIII.	16
IV.	27	IX.	42
V.	16	X.	26

Century.	Comets observed in Europe and China.	Century.	Comets observed in Europe and China.
XI.	36	XVI.	31
XII.	26	XVII.	25
XIII.	26	XVIII.	64
XIV.	29	XIX. (first half)	80
XV.	27		

Giving a total of 607.

The duration of a comet's visibility varies from a few days to more than a year, but it most usually happens that it does not exceed two or three months. Much depends on the apparent position of a comet in reference to the sun's place, on its distance from the earth, and particularly on its intrinsic brightness, or rather, we should say, on its capability of reflecting the sun's rays. Some of these bodies have been observed at a far greater distance from the earth and sun than others. The remarkable comet of 1729 never approached nearer to the sun than *four* times the earth's mean distance from that luminary, yet it was seen without any great optical aid for nearly six months. That discovered by Colla, in May, 1847, was also followed till its distance from the earth was three-and-a-quarter times the distance of our globe from the sun, and another found in the same year by Mauvais was visible in the large telescopes at several observatories in this country, till it had receded to nearly three times that distance. In both these instances the comet's distance from the sun was equally great. Many of these bodies, on the contrary, fade away even in the most powerful instruments we possess, before they have attained anything like a distance equal to the diameter of the earth's orbit.

Amongst those comets which have continued longest in sight, we may mention the following:—

A.D.		
60	(in China)	135 days.
64	(according to Seneca)	180 days or more.
247	(in China)	156 days.
1729	. . . . . .	171 "
1773	. . . . . .	184 "
1807	. . . . . .	188 "
1811	. . . . . .	510 "
1815	. . . . . .	172 "
1825	. . . . . .	358 "
1835	. . . . . .	286 "
1844	(Mauvais' comet) . . .	246 "
1847	(Colla's comet) . . .	240 "
1847	(Mauvais' comet) . . .	285 "

The first three comets in the above list were of course observed without the assistance of a telescope, the others have all been followed with optical aid. That of 1835 was *predicted*, and therefore discovered much sooner than it is probable it otherwise would have been. In several cases the comets have not remained visible throughout the whole period, but after disappearing for some days or weeks in the sun's rays, have become conspicuous again on the other side: in these instances we have given the interval between the earliest and latest observations as sufficient for our present purpose. It would appear that out of the many hundred comets recorded in history, only six have been observed so long as eight months, and these six instances have all occurred during the present century. There are some few comets which have only been seen once, unfavourable weather

preventing further observation. In these cases we cannot ascertain any particulars respecting their distances, or real paths in space.

The lengths of the apparent tracks of comets in the heavens, during the time of visibility, varies greatly, being dependent on the distance of the body from the earth, and on the direction of its real movement, in reference to that of our globe. The comet of 1729 which, as already remarked, was always very remote from us, traversed an arc of only 15° during the six months it continued in view, while that of 1769 passed through an arc of 240° in longitude; and another in 1825, which moved extremely slow at first, (the change of right ascension and declination in ten days being little over two degrees), subsequently quickened its rate of progress, and traversed an arc of 225°.

It is possible that a comet may be so situated in reference to the earth, as to appear to pass through no less than 140° in the space of an hour, or 178° in a day; but the combination of circumstances necessary to produce this enormous change in the apparent positions, has never yet taken place: the real motion of the comet must be retrograde or contrary to that of the earth in its orbit, it must be in opposition to the sun, and in perihelion, moving in the plane of the ecliptic, and at a distance from us not exceeding that of the moon. If a comet be moving in the same direction as the earth, the distance of the two bodies being small, its apparent position may scarcely change in the course of the day, and if it be advancing *towards* the earth, the same, or nearly the same place

in the heavens, may be preserved for many weeks, as in the case of the comet of 1825, to which we have just alluded.

When a comet is conspicuous to the naked eye, it consists, in nearly every case, of a roundish and more or less condensed mass of nebulous matter, termed the *head*, from which issues, in a direction opposite to that nf the sun, a train of a lighter kind of nebulosity, called the *tail*. Sometimes the centre of the head is occupied by a starlike point or *nucleus*; at others by a well-defined planetary disk, while in by far the greater number of instances, it exhibits nothing more than a higher degree of condensation of the nebulous matter, which always has a confused appearance in the telescope. Occasionally a low magnifying power will afford evidence of the existence of a stellar nucleus, but, on applying higher magnifiers, this appearance vanishes, the light towards the centre being merely of greater intensity than at the borders, without coming up suddenly to a point, so as to resemble a star. *Telescopic comets* are generally destitute of a tail, and appear most commonly as roundish nebulosities, strongly condensed towards the centre, but without any decided nucleus. There are exceptions, however, to this rule, as we shall presently find. The same comet may put on at different times of its visibility, every variety of figure and general appearance from the dim nebulous spot hardly discernible in the telescope to the 'cometa terribilis,' 'horrendæ magnitudinis,' the tailed and hairy stars which spread so much alarm amongst our forefathers, before science showed the groundlessness of such fears. These

changes in the aspect of the same comet, are caused by variation in its distance from the earth and sun, by its position in respect to the former, and possibly also in some degree by actual change in the form of the comet itself.

The *envelope*, mentioned by astronomers in their observations of large comets, consists of a border of light surrounding the head on the side near the sun, and passing round in each direction, so as to form the commencement of the tail.

The *Coma* is the nebulosity which surrounds a highly condensed or planetary nucleus.

Some comets have attained such an extraordinary degree of splendour, as to be distinctly visible at noon-day, or to render the stars dim by contrast, and cast sensible shadows at night. A comet mentioned by Diodorus Siculus, was so brilliant as to cast shadows during the night, as strongly marked as those formed by the moon. Another, which appeared, according to Seneca, shortly before the war of Achaia, B.C. 146, was as large as the sun, and dissipated the darkness of the nights: its disk was red and fiery. The comets recorded by Justin, at the time of the birth and accession of Mithridates, rivalled the sun in splendour. One observed in February, 1106, was seen close to the sun all over Europe. That of March, 1402, was visible day and night in the circumpolar regions of the heavens, in Germany and Italy; and another grand comet in the summer of the same year, was bright enough to be discerned before sun-set. The second comet of 1618, was distinctly seen in full daylight by Marsilius, in Bohemia. The comet of

March, 1843, by far the most imposing of the present century, was discovered in various parts of the world, two or three degrees only from the sun's limb: it must have far exceeded the planet Venus in brilliancy. Instances are on record where comets have become visible during an eclipse of the sun, a circumstance indicative of great intrinsic splendour, since stars of the second magnitude are not very readily discerned on such occasions. Philostorgius says, that on the 19th of July, 418, when the sun was eclipsed, and stars were visible, a great comet, in the form of a cone, was discovered near that luminary, and was afterwards observed during the nights. The comet of 1744 was observed with the telescope at noon-day, and some persons were able to follow it without optical aid for a considerable time after sunrise. The first comet of 1847, discovered by the author, was seen for some hours about two degrees from the sun's limb, with a powerful telescope, and is the last instance of the kind on record.

In most comets the head is white, or has a pale watery appearance. Occasionally, however, the more condensed part has a dull reddish or yellowish tinge, or more rarely inclines to green. Out of *forty-nine* instances, in which the colours of comets were recorded by the Chinese, we find *twenty-three* were white, *twenty* bluish, *four* red or reddish-yellow, and *two* greenish.

Planetary nuclei in comets, are of rare occurrence, and it is pretty certain that they consist of nothing more than nebulous matter in a very high degree of condensation, and are not to be regarded as solid

bodies. It is questionable whether any comet has yet exhibited during the whole of its visibility, a well defined disk of the same magnitude and appearance: changes of form and apparent diameter are observed, which clearly indicate a gaseous nature, or at any rate are conclusive against the idea of solidity.

The nucleus of the great and celebrated comet of 1680 is described by some observers as resembling 'a burning coal—red and glowing;' and the same simile is used by Struve, in reference to the appearance of Halley's comet during the autumn of 1835. Some comets are pale and livid, as that of 1652,—stated by Comiers and Hevelius to be equal to the moon in apparent size. Others, like that of 1744, are bright and dazzling. The head of the fine comet of December 1618, is said to have been composed of several bright points or nuclei: Cysat observed three or four on the 8th of that month, and on the 20th the head seemed to be a cluster of small stars. Hevelius mentions something analogous in the appearance of the comet of 1661 and 1665; such phenomena are to be attributed to changes in the gaseous envelope of the nucleus. We are not aware that they have been remarked in any of the larger comets of recent times.

Though, as we have seen, the nuclei of comets have occasionally attained so great a degree of brightness as to be discernible in full daylight, or to cast shadows at night, it is their tails or trains which give them so imposing an appearance in the heavens, and which have excited so much astonishment in all ages. But very few of the brighter comets have been observed

without an appendage of this kind, though the telescopic class rarely appear otherwise than as roundish nebulosities. In some comets the tail has been observed as a long narrow ray of light, somewhat brighter near the head, and gradually fading away into darkness. In others a dark line has divided it into two branches, and instances are on record where two tails, evidently distinct from each other, have been remarked. Other comets have bushy, fan-shaped tails, compared by the ancient observers to the train of a peacock. Not unfrequently the appearance of the tail will vary greatly on successive evenings, or even during the same night.

As a general rule, the tail of a comet is turned *from the sun*, forming a prolongation of the radius vector, or of the line joining the sun and comet. This remarkable fact was first noticed by Peter Apian of Ingoldstadt, who found it the case with the trains of five conspicuous comets which he observed between the years 1531 and 1539. Exceptions do, however, occur. The tail of the comet of 1577 deviated 21° from the line joining the sun and comet, and that of the comet of 1680, nearly 5°. In some few instances where more than one tail has been observed, the second has extended towards the sun, as was the case with a comet discovered in October, 1851. That which appeared in January, 1824, exhibited two tails, both distinctly visible to the naked eye, forming with each other an angle varying from 138° to 170°: one tail was in the usual direction, and appeared shorter but brighter than the second, which streamed off from the nucleus towards the sun. A fine comet, visible in

the southern hemisphere early in 1845, had, in addition to a lengthy tail turned from the sun, a second narrow ray of light, forming an angle of about 140° with the other.

A comet mentioned by Diodorus Siculus, and observed by Aristotle in the year 371 B.C., exhibited a train 60° long. Another, in the year 133 after the Christian era, was attended by a tail 50° long and 2° broad, according to the Chinese observations. The comet of 178 had an appendage of equal length. That of 390, observed in Europe and China, is said to have had a train of the enormous length of 100°. The grand comet of 837, mentioned by nearly all the historians of the time, was remarkable for the length of its tail: on April 10th it extended 50° from the head, and was divided near the extremity into two branches; next day its length was 60°, but only one ray was visible, and on the 14th it had increased to 80°. Another great comet in 1264 was accompanied by a train fully 100° long, agreeably to the Chinese description, while European contemporaries tell us, when the head was just clear of the eastern horizon, the tail stretched past the mid-heaven westward, which seems to indicate an extent of more than 90°. The comet of 1362 is said to have had a train 100° long, as observed in China: in Europe it was described as a 'very great and brilliant star.' The comet of 1456, known as Halley's, which created so much alarm amongst the Turks, was accompanied by a tail 60° in length. The great one, which appeared in the winter of 1618, exhibited a tail no less than 104° long, according to Longomontanus, the Danish

astronomer. Kepler had observed it fully 70° in length a day or two previous. The famous comet of 1680, which was attentively watched by Newton and Halley, was attended by a train 90° long. That observed in the southern hemisphere in 1689, had a tail more than 60° in length, and was two hours and a half in rising; and in another which appeared six years afterwards, the tail was nearly of equal magnitude. The comet of 1769 was attended by a long and conspicuous tail, but observers differ considerably in their estimations of its apparent length, even on the same day, which can only be attributed to the state of our atmosphere at the various stations. This circumstance had been previously noticed in reference to the comet of 1680, but it was more marked in the present case. Thus on the 9th of September, 1769, Maskelyne at Greenwich considered the length of the tail 43°; at Paris it was judged to be 55°; at the Isle of Bourbon, it was traced 60° and more by La Nux, while Pingré saw it fully 75° long, being at sea at the time, between Teneriffe and Cadiz. Two days afterwards, this astronomer found it 90° long, while La Nux traced it 97° from the nucleus. The only comet of the present century which has been accompanied by a tail of very great length, is that of 1843, its average extent was about 45°, but on one occasion a narrow ray of light attained the enormous distance of 65° from the head.

It would lead us far beyond the limits of the present work, were we to particularize all the varied phenomena which have been observed in the tails of comets, but there is one singular appearance in the

trains of great comets which we must not pass over in silence. It consists of apparent vibrations or coruscations, similar to the pulsations peculiar to the Aurora Borealis. These vibrations commence at the head, and appear to traverse the whole length of the tail in a few seconds of time. The cause was long supposed to be connected with the nature of the comet itself, but Olbers pointed out that such appearances could only be attributed to the effects of our own atmosphere. The reason is this: the various portions of the tail of a large comet must often be situated at widely different distances from the earth, so that it will frequently happen that light would require several minutes longer to reach us from the extremity of the tail than from the end near the nucleus. Hence, if the coruscation were caused by some electrical emanation from the head of the comet, travelling along the tail, even if it occupied only one second in passing over the whole distance, several minutes must necessarily elapse before we could see it reach the end of the tail. This is contrary to observation, the pulsations being almost instantaneous.

Gregory of Tours mentions a comet in January 582, the train of which resembled the smoke of a distant conflagration, a description which may perhaps have some relation to these vibrations or coruscations. The first distinct mention of the phenomenon is to be found, we believe, in the Chinese Annals in reference to the comet of 615, the tail of which was between 50° and 60° long, and during the night had a kind of libration to and fro. Kepler says the tail of the comet of 1607 was short one moment, but extended itself in the

twinkling of an eye. Longomontanus, in describing the immense tail of the comet of 1618, states that it had 'an enormous vibration,' and Father Cysat says it appeared as though it had been agitated by the wind; the same phenomenon was remarked by Kepler, Wendelin, and other observers of this splendid comet. Hevelius noticed similar undulations in the tails of the comets of 1652 and 1661, and Pingré says he had observed them in the train of that which was visible in 1769. The pulsations were very distinctly seen in the tail of the grand comet of March 1843, and they have been remarked in a greater or less degree in other cases.

Another curious phenomenon occasionally observed in the tails of comets is a *curvature* of the extremity, or of a greater or less portion, so as to give the whole train the form of a sabre. The ancient historians frequently make use of this simile in describing the aspect of these bodies. The comet which appeared about the time of the Battle of Salamina, A.D. 479, was of this form, as also those observed at Constantinople in 912, 1340, 1402, 1456, and many others. The Chinese compare the tail of the comet of 1232 to the tusk of an elephant. The grand comets of 1264, 1618, and 1689, exhibited curved tails 80° or 100° in length, the latter being particularly described by an observer in the southern hemisphere as having a striking resemblance to 'a great sabre.' Pingré noticed a curvature in the tail of the comet of 1769, the convexity towards the north, and at times a second small arc was formed near the extremity, turned in the opposite direction; the same appearances were

remarked by La Nux at the Isle of Bourbon. The train of the last great comet in 1843 was very sensibly bent downwards towards the horizon at the end of March, when it became conspicuous in this country, and the smaller comet of December and January 1844-5 exhibited the same phenomenon.

CHAPTER II.

OF THE REAL DIMENSIONS OF COMETS—PHASES OBSERVED IN SOME OF THEM—THEIR PHYSICAL CONSTITUTION — CHANCES OF COLLISION WITH THE EARTH.

HAVING described the *apparent* dimensions of various comets we must now say a few words relative to their real magnitude. When the distance of one of these bodies is known, and we have observed the angular diameter subtended by the nucleus or head, it becomes a very easy matter to ascertain the true diameter in the same way that we find the dimensions of the sun, moon, and planets. But as it never happens that the borders of the nebulosity are sharply defined, and but rarely so as regards the nucleus, our determinations of their real dimensions are necessarily open to a good deal of uncertainty. One thing, however, is quite certain, that the cometic atmosphere surrounding the nucleus varies greatly in extent in different comets, and even in the same body at different epochs during its visibility. The actual length of the tail of a comet may be computed by trigonometry, when we know the distance of the nucleus from the earth and its position in respect to the sun, always assuming that

the tail is projected *from* the sun in the line joining that luminary and the head of the comet.

The following were the real diameters in English miles of the nuclei of some of the more remarkable comets, which have been satisfactorily measured within the last century:—

	Miles.
The comet of 1815, discovered by Olbers	5300
The great comet of 1825	5100
The great comet of March, 1843	5000
The first comet of 1780	4270
The first comet of 1847, discovered by the author	3500
The fine comet of July, 1819	3280
Second comet of 1811, measured by Herschel	2640
The great comet of 1807, measured by Herschel	538
The celebrated comet of 1811, measured by Herschel	428
The second, of 1798, according to Schröter and Harding	125
The comet of 1805, known as Biela's	70 to 112

The comet which was visible to the naked eye in June 1845 had a bright planetary-looking nucleus, which must have been nearly 8000 miles in diameter, or about equal to that of the earth. On the 24th of January, 1836, Mr. Maclear, at the Cape of Good Hope, saw a well-defined disk within the head of the comet of Halley, which, from the apparent diameter assigned, could not have been less than 97,000 miles in breadth, but in the previous autumn the very same comet had exhibited a brilliant 'kernel,' or nucleus, varying on different dates from 250 to 1000 miles in diameter. A more striking proof of the variable dimensions of a comet could hardly be adduced.

The coma, or atmosphere enveloping the nucleus,

or more condensed part of a comet, is subject to the same variation, as the subjoined results will show:—

	Diameter of Head.
The grand comet of 1811 . .	1,125,000 miles.
Comet of Halley, 1836 . . .	357,000 „
Comet of Encke, 1828 . . .	312,000 „
The first, of 1780	269,000 „
The first, of 1846	248,000 „
The comet of Lexell, 1770 . .	204,000 „
The third, of 1846	130,000 „
The second, of 1849	51,000 „
The first comet of 1847 . . .	25,500 „
The fifth of the same year . .	18,000 „

During the autumn of 1811, or while the splendid comet of that year was visible to the naked eye, the real diameter of the head appears to have differed but little from 1,000,000 miles, or more than four times the distance which separates the moon from the earth. No other on record has surpassed this. In most instances the visible atmosphere of a comet is less than 100,000 miles in diameter, and but very rarely exceeds 200,000. It must be remembered, however, that the nebulosity may extend much further than we can trace it from the earth, and consequently that our estimates of the true magnitudes are very likely to be under-rated.

It has been remarked above, that the real dimensions of comets are found to vary greatly at different dates during their visibility. Contrary to what we might have expected, there is no doubt that many of these bodies *contract* as they approach the sun, and *dilate* on receding from that luminary. We have the

strongest proofs of this in the case of Encke's comet, which is one of short period, and has been repeatedly observed, as we shall notice more at length presently. This comet arrived at its least distance from the sun on the 10th of January, 1829, and the following were its actual dimensions on the various dates of observation during its descent towards the sun :—

1828.	Diameter in Miles.	Distance from Sun.
October 28	312,000	1·46
November 7	257,000	1·32
November 30	119,000	0·97
December 7	79,000	0·85
December 14	46,000	0·72
December 24	14,000	0·54

The observations of the same comet ten years later furnish another instance. It was at its least distance from the sun on the 19th of December, 1838, and found to have had the following diameters on different days preceding the arrival at perihelion.

1838.	Diameter in Miles.	Distance from Sun.
October 9	281,000	1·42
October 25	120,500	1·19
November 6	79,000	1·00
November 13	74,000	0·88
November 16	63,000	0·83
November 20	55,500	0·76
November 23	38,500	0·71
November 24	30,000	0·69
December 12	6,600	0·39
December 14	5,400	0·36
December 16	4,250	0·35
December 17	3,000	0·34

The nebulosity surrounding the nucleus of the great comet of 1807 *expanded* as the distance from the sun

increased. The measures of Schröter give the following diameters, expressed as before in English miles. The comet was nearest to the sun on September 19th:—

1807.		Diameter in Miles.	Distance from Sun.
October	20	117,900	0·92
October	21	125,800	0·93
October	22	133,500	0·94
October	23	138,400	0·96
October	25	156,200	0·99
October	31	159,000	1·08
November	3	198,400	1·12

Kepler first remarked this singular contraction and expansion of the nebulosity surrounding the nucleus of a comet as it approaches and recedes from the sun respectively, in the case of the fine comet which appeared in the year 1618.

The tails of comets in some cases extend only a few hundred thousand miles from the nucleus, while in others they are projected to the astonishing distance of one hundred or one hundred and fifty millions of miles, or even more. The train of the first comet of 1847 was 5,000,000 miles in length; of the beautiful comet of 1744, 19,000,000; of the comet of 1769, about 40,000,000. The third of 1618 had a tail more than 50,000,000 miles in length, when it crossed the plane of the earth's orbit about the 25th of November, and it was subsequently of greater extent. The great comets of 1680 and 1811 had trains considerably more than 100,000,000 miles long; and the second of the latter year was accompanied by a tail 130,000,000 miles in length. Even these comets, however, were surpassed by the grand one which attracted so much

attention in 1843, and which exhibited a brilliant train that on different dates was found to attain the enormous distances of 150, 180, and 200 millions of miles from the head! If such a comet had been in the plane of the ecliptic, and close to the sun, the train would have extended far beyond the orbits of the Earth and Mars, terminating amongst those of the minor planets. Yet this wonderful appendage was formed in less than three weeks.

It has frequently been remarked, that, if comets shine by reflected light, and there be anything like solidity in the nucleus, we ought at certain times to observe *phases* similar to those presented by the moon in the course of her revolution round the earth. There are some few instances on record where such appearances have been noticed. We cannot place much reliance on the cometary nature of the object mentioned in the *Chinese Annals* as having been observed in the northern heavens in October 684, which resembled a half moon, or of that recorded by the historians of the ninth century, at the beginning of the reign of Leo the Armenian in 813, said to have been like two moons joined together. Something very closely analogous to a phase was, however, observed in the head of the fine comet of 1744, and in another large one of the same century (1769), an observer expressly states that he had seen the nucleus first as a thin crescent, and subsequently as a half-moon, in the course of the comet's descent towards the sun. The nucleus of the comet of 1819 presented a very distinct crescent, according to Nicholas Cacciatore, of Palermo.

Concerning the physical constitution of comets we have but a very imperfect knowledge at present. Sir John Herschel regards them as masses of thin vapour, capable of reflecting the solar rays from their internal as well as external parts—an inference which is rendered necessary, in order to account for all the phenomena revealed by telescopes. It is certain that stars of a very faint class have been repeatedly seen through comets of from fifty thousand to one hundred thousand miles in diameter, and, in the majority of cases, not the least perceptible diminution of the star's brightness took place. There are one or two instances on record, where astronomers have been convinced of a sensible increase of brilliancy when a star has been viewed through the cometic vapour. In addition to a remarkable observation of this kind by Piazzi, at Palermo, during the appearance of the grand comet of 1811, we may mention a more recent one by Professor Reslhuber of Kremsmünster, in reference to a star seen through the denser part of a comet discovered by M. Brorsen in March 1846, and which, under ordinary circumstances, belonged to the eighth class, or was just beyond unassisted vision. When the star was centrally covered by the comet, it became very considerably brighter, and was judged to be equivalent to a star of the sixth magnitude, in which case it would have been distinctly visible without a telescope. Professor Struve made some interesting observations during the transit of the comet of Biela over a small star, on November 6th, 1832. The brightness of the star was not in the least diminished by the intervention of the comet, and its light suffered no perceptible

refraction, a point established by a continuous series of measures with the micrometer.

That comets shine by a reflected light is a conclusion which few astronomers will dispute. It is evident from telescopic observation of the degree of brilliancy at different distances, and in various positions of a comet, with respect to the sun and earth, and M. Arago has established the fact from experiments with a polariscope, during the visibility of the famous comet of Halley in the autumn of 1835. Still the variation in the intensity of light is not universally such, as should follow if the comet merely reflected the sun's rays, under certain permanent conditions, and we are under the necessity of looking to physical causes inherent in the body itself for an explanation of some few observations which appear irreconcilable with the theory of reflected solar light. The first comet of 1780 was closely examined by Dr. Olbers, the eminent astronomer of Bremen. He found it attained its greatest brightness on the 8th of November, thirteen days subsequent to its discovery, whereas, according to the law of reflected light, it should have become gradually fainter since the first observation ; and, supposing the comet self-luminous, the intensity of light should have increased each day until November 26, when the maximum would take place : yet, in the interval between the 8th and 26th of that month, it grew rapidly less. The comet discovered by Dr. Galle, of Berlin, on the 25th of January, 1840, presented similar anomalies. Assuming that it had no light of its own, it should have appeared twice as bright on the 23rd of February as on the 21st

of March, yet at the latter date Professor Plantamour found the intensity of light had *increased* in the proportion of more than two to one. Such variations are probably to be attributed to changes in the physical constitution of the comet, due to the action of the sun.

With our present imperfect knowledge of the nature of the matter of which these bodies are composed, it is not to be expected that we can gain a clear insight into the laws of the forces exercised upon it, through which the envelope and tail are formed. The nucleus, or more condensed part of the head, appears to possess the power of throwing off towards the sun a portion of the cometic atmosphere, which, before it can attain any great distance from the nucleus, is driven backward in two streams passing on either side of the head, and ultimately blending into one to form the tail. This repulsive energy must very far exceed the force of gravitation. Generally speaking, the axis of the tail preserves a rectilinear form throughout the greater part of its length, a curvature of the extremity being only occasionally seen, and probably attributable to the failure of the repulsive force, and the gradual effect of a resisting medium upon these distant and extremely rare portions of the train. The disappearance of the tail as the comet recedes from the sun, may be owing either to its being attracted into the nucleus as that luminary loses its power upon it, or it may be partly dispersed in the surrounding space.

In the case of bodies like comets, moving through the planetary spaces in every direction, it cannot

be denied that there is a *possibility* of the Earth's coming in collision with one of them in the lapse of time; but we are able to show from legitimate reasoning that the chance of such a catastrophe is very small indeed. M. Arago has calculated that the probability against it is greater than 250,000,000 to one. We know that the earth has had one or two narrow escapes within the last two centuries, as in 1680 and 1832, when comets crossed the plane of the ecliptic almost on the path of our globe, though at these times we were, perhaps fortunately, removed many millions of miles from the dangerous part of the orbit. The comet of 1770 has approached nearer to us than any other of these bodies whose elements have been sufficiently well determined. On the 1st of July it was distant from the Earth only 363 terrestrial semidiameters or 1,438,000 miles. The great comets of 837, 1402, and 1472, must have come within a very short distance from our globe, and another small one, which was observed by Flaugergues in 1826, seems to have made a close appulse. Olbers mentions several which have crossed the ecliptic at points not far removed from the annual track of the earth.

The comet of	1684	approached it within	216	terrestl. semidiamtrs.
That of	1805	„	261	„
That of	1742	„	331	„
That of	1779	„	347	„

CHAPTER III.

OF THE PATHS OF COMETS IN SPACE—ELEMENTS OF THEIR ORBITS—USES OF A TABLE OF ELEMENTS—EFFECTS OF PLANETARY ATTRACTION UPON THEIR MOVEMENTS.

THE curve described by the generality of comets is in all probability a very excentrical ellipsis, so nearly approaching a parabola, that for those parts of the orbit near the perihelion, where alone the comet is visible from the earth, no sensible difference is caused by the substitution of the latter curve; and accordingly, as the calculation in the parabola is so much easier and shorter than in the ellipse, astronomers always employ it to represent the paths of comets in the heavens, and to predict their future positions as viewed from the earth or sun. When one of these bodies has been discovered, and several observations (not less than three) have been obtained, they are submitted to calculation; and the *elements of the orbit*, as they are termed, are found on the supposition that the real path through space is in a parabola: with these elements we can find for any particular time, the comet's distance from the earth, and its situation in our heavens, and, in fact, trace its

course through the system. The major-axis in this conic section being infinite, we can learn nothing respecting the period of revolution round the sun from such computations; but for all practical purposes they are usually found to be sufficiently exact without having recourse to the ellipse. If we wish to approximate to the periodic time, we must enter upon a much longer investigation, and one which may not always prove satisfactory or trustworthy in the end. Sometimes ellipses with periods widely different will represent the observations of a comet with nearly equal accuracy, none of them perhaps being much preferable to a parabola; in such a case it is tolerably certain that the revolution is of many centuries' duration, or more probably extends to many thousand years. Still some few comets have been observed, whose apparent paths amongst the stars could be in no wise represented by a parabolic curve: elements which appear satisfactory, for the earlier observations would give places at later periods, deviating several degrees from the true situation of the comet. In such cases astronomers have resorted to the ellipse, and it has been found that the comets are revolving in comparatively short periods, varying from three to seventy-five years. In fact, of these periodical comets there are two well-marked classes,—one having the major-axis not very different from those of the minor planets between Mars and Jupiter, and the other having mean distances rather less than in the case of Uranus. These bodies are amongst the most interesting objects in the heavens, and of high importance to the physical astronomer.

The elements, as they are termed, of a parabolic orbit, are five in number :—

1. The *time of perihelion passage*, or the moment when the comet arrives at its least distance from the sun, at the vertex of the parabola. English calculators adopt the meridian of Greenwich, the French that of Paris, and the Germans that of Berlin, in expressing the epoch of arrival at perihelion.
2. The *longitude of perihelion*, or the longitude of the comet at the time it reaches this point, as viewed from the sun's centre. It is usually reckoned on the ecliptic to the node, and thence on the orbit, so that the differences between the longitudes of the nodes and perihelia, as commonly given, are arcs of true anomaly.
3. The *perihelion distance*, or the distance of the comet from the sun at that epoch expressed in parts of the Earth's semi-major axis, taken as unity.
4. The *longitude of the ascending node* of the comet's orbit upon the ecliptic, as seen from the sun.
5. The *inclination of the orbit*, or the angle between the planes of the orbit and of the ecliptic.

It is also necessary to know whether the comet moves in the order of the signs or in the contrary direction : in the former case its movement is said to be *direct ;* in the latter, *retrograde.*

In an elliptic orbit, in addition to the five elements

above named, we require also to know the *excentricity;* from which and the perihelion distance we can ascertain the length of the major-axis, and thence the periodic time. The quantity termed the excentricity in this case is not the linear distance of the centre of the ellipse from the focus, but the ratio of that quantity to the comet's mean distance or half the greater axis. Occasionally it is expressed as an angle, which is actually formed by the minor-axis at its extremity on the border of the ellipse, with a line drawn thence to the focus. The greater this angle, the more excentrical is the orbit.

Up to the year 1850, the elements of about two hundred comets have been determined with a greater or less degree of accuracy, according to the goodness or otherwise of the observations. Out of this number there are thirty-three which appeared before the end of the sixteenth century, and were chiefly observed in China. In these cases the orbits are founded upon the details preserved in the Chinese annals, which, imperfect and vague as they frequently appear, are yet far superior to the generality of European accounts in these early times. MM. Stanislaus Julien and E. Biot of Paris have added much to our previous knowledge of the early Chinese observations. The first cometary orbit in our catalogue belongs to the body observed and described by Aristotle, 371 years before the Christian era.

The value of the orbital elements, whether parabolic or elliptic, is not confined alone to their practical application during the visibility of a comet—to trace it amongst the stars, and predict its apparent positions

at any time; if it should be found, on comparing the elements of a comet newly discovered with any previously computed, that a great similarity exists between them, it is a strong argument in favour of the identity of the comets to which they refer, and such comparison affords the most certain means of ascertaining the period of a comet, when it extends to many centuries. The direct solution of the problem of finding the time of revolution frequently fails, from want of a sufficiently long series of observations, and other causes.

Out of 194 comets calculated before the year 1849, it appears that 94 were *direct* and 100 *retrograde*, and that one-third of the whole number have arrived at perihelion between the autumnal equinox and the winter solstice. The perihelion distances are thus distributed:—

Between 0·0	and 0·5	. .	54	comets.
„ 0·5	„ 1·0	. .	95	„
„ 1·0	„ 1·5	. .	31	„
„ 1·5	„ 2·0	. .	8	„
Beyond 2·0		. .	6	„

The comet of 1729 had the greatest perihelion distance, = 4·04, and that of March, 1843, the least, being only 0·005678.

The paths of the comets through the Solar System are usually influenced in a very sensible degree by the attractions of the planets, and especially of Jupiter, which from its great mass has on more than one occasion entirely overpowered for a time the action of the sun, and thereby changed *in toto* the

nature of the comet's path about that luminary. The calculation of the effects of these perturbations is one of great intricacy, and attended with considerable difficulties in practice, and astronomers resort to various artifices to shorten the labour of calculation and simplify the analytical process. Where the amount of attraction exercised by two or more bodies upon a third has to be considered, the problem of finding the effect upon the motion of the third becomes exceedingly complicated, and in fact it is not possible to solve it directly. The method in general use at present is virtually as follows:—Suppose the effect of the Earth, Jupiter, and Saturn upon the longer diameter of a comet's elliptic orbit is required between January 1 and June 1—*i. e.*, having the value applying to January 1 we wish to find what it would be at the beginning of June. The interval is divided into certain equal periods, and for the middle day of each period, the *diurnal* variation of every element of the comet's orbit is computed *separately for each planet*, as if the others did not exist; the variations produced by each are then summed, and give the total change in the element in the adopted unit of time, commonly one day; then by a process which we cannot explain here, the quantities are applied to the assumed value of the longer axis of the ellipse on January 1, having been previously multiplied by the number of days (if a day be the unit of time) in each interval, so as to give the value for the epoch required, or June 1. The accuracy of this method depends mainly upon the judgment exercised by the calculator in shortening his intervals, so as to determine the

amount of the diurnal variations with sufficient frequency; sometimes intervals of fifty days would be short enough, at others it might be necessary to resort to intervals of twelve, eight, or even four days, or less, according as the attraction of the disturbing body varies in a lesser or greater degree in each interval; because it is assumed that the changes go on uniformly, or nearly so, and consequently that the diurnal variation for the middle day of each interval, if multiplied by the number of days included in it, shall give very nearly the true variation in that interval. By another method, instead of using equal periods of time, the calculations are conducted for equal intervals of the comet's excentric anomaly. These processes, to be fully understood in theory, require an acquaintance with some of the highest branches of mathematical science, while their practical application is so tedious and intricate, that few but the most zealous and expert computers will attempt to manage them.

We have just alluded to the use of a table of the elements of cometary orbits in identifying returns of the same body. By this comparison of elements the periodicity of at least one comet has been established, and we have strong reasons to suspect it in other cases. In the following chapter we shall briefly describe the circumstances which led our countryman Halley to the first discovery of the periodical return of a comet, while he was occupied in applying Newton's law of gravitation to the apparently capricious and intricate movements of these bodies; by the application of the Newtonian principles at a vast expense of time and labour, Halley laid the founda-

tion upon which cometary astronomy has since risen. We shall endeavour so to arrange our descriptions of this and other comets, that the reader may gain an insight into the *kind of interest* attaching to this department of the science, and the difficulties with which astronomers have to contend in prosecuting their inquiries respecting these extraordinary bodies.

CHAPTER IV.

THE COMET OF HALLEY.

AMONGST the comets which particularly attracted the attention of Dr. Halley during his arduous investigations, were those of 1531, 1607, and 1682.

For the most important observations of the comet of 1531 we are indebted to Peter Apian, astronomer to the Emperors Charles V. and Ferdinand I. of Austria, who observed at Ingoldstadt in Bohemia. His results were published in 1540 in the *Astronomicum Cæsarium*, an extremely rare work, which was found with difficulty even so long since as the time of Halley. A fine copy is now preserved in the library of the Royal Astronomical Society. The observations were made each evening at the time of transit of the bright star Arcturus over the prime vertical westward, and extend from August 13th to the 23rd, Julian style. The comet was first seen at the end of July, and was visible in some parts until the beginning of September, its motion in the interval being from Leo into Libra. Lavather says it was observed in Italy, Germany, and France, and was of a reddish or yellow colour. Camerarius says it belonged to the class *Pogoniæ*. The Chinese astronomers found the comet in Gemini on August 5th, and it was last perceived on the 8th of September in the constellation

Virgo; they describe its course amongst the stars, agreeing in every essential point with the relation of Peter Apian.

On the 11th of September, 1607, the Chinese discovered a comet in Gemini, which they finally lost sight of in the sign Scorpio at the beginning of October. In Europe it was observed by the celebrated Kepler at Prague, by Longomontanus at Copenhagen, and at Malmoge, in Scania, by William Lower at Ilfracombe, and by our distinguished countryman Harriot. Kepler's observations are found in a work published at Augsburg in 1619, and entitled, *De Cometis libelli tres.* Professor Rigaud has printed in detail the observations of Lower and Harriot, which had been fortunately discovered amongst the papers of the Earl of Egremont. According to Longomontanus, the comet had a pretty long and dense tail in a direction opposite to that of the sun. The head appeared of about the size of Jupiter, its colour being livid, and resembling that of Saturn; the tail was visible from the time the comet was first perceived by Kepler, on September 16th, until the 12th of the following month. The head was not quite round; it had a pale watery light; the tail long and glittering. Gottfried Wendelin saw the comet till November 5th, and says its form was like that of "a burning lamp," or "a flaming sword," 7° long. Coruscations of the tail were remarked by Kepler and others. The apparent path was through Ursa Major, Bootes, Serpens, and Ophiuchus.

On the evening of the 15th of August, 1682, Flamsteed's assistant saw a comet at the Royal Observatory,

Greenwich. A few days later it was more visible; the tail 5° long, the diameter of the head about two minutes of arc. On the 21st the tail was 10° long, and bent towards the right. Flamsteed's observations extend to September 9th, when the head was dull, and scarcely visible in the twilight. Halley saw it a day later. Picard found the comet at Paris on August 26th; the head then appeared as large as a star of the second magnitude. On the 29th the tail was curved, the concavity on the eastern side. On September 11th the head was so confused that it was not without difficulty a luminous point could be perceived. Picard's observations extend to September 12th. Hevelius, who observed the comet at Dantzic, says it was bright at the end of August, and could be seen all night with a tail from 12° to 16° long. In large telescopes a nucleus of an oval or gibbous form was constantly remarked. On many occasions the tail was not directed exactly *from* the sun. About September 8th a kind of luminous ray or sector was thrown out from the nucleus into the tail, a phenomenon which appears to have struck Hevelius as very remarkable, and induced him to give a figure, which conveys a better idea of its nature than could have been obtained from verbal description. The same phenomenon was witnessed at a subsequent return of this comet. Besides the observers we have named, Kirch of Leipsic, Zimmerman of Nuremberg, Bäert of Toulon, and Montanari of Padua, are amongst those who have left descriptions or observations of this body.

Dr. Halley calculated the parabolic elements of the comet of 1682 from Flamsteed's observations, agree-

ably to the rules laid down by his friend Sir Isaac Newton; and having also determined the orbits of the comets of 1531 and 1607, he was immediately struck with their similarity, and suspected, from 'the like situation of their planes and perihelions, that the comets which appeared in the years 1531, 1607, and 1682 were one and the same comet, that had made three revolutions in its elliptical orbit.' As some differences existed in the periods and inclinations which Halley thought rather large, he merely hinted his suspicion, when the *Synopsis of Cometary Astronomy* was first given to the world in the year 1705. At a subsequent period he became much more convinced of the identity of the comets, and remarking that the next revolution would be sensibly affected by the planet Jupiter, he thought the return to perihelion might be delayed till the beginning of the year 1759. In advising the astronomers of that day carefully to watch for the re-appearance, he expressed a hope that in the event of its return, they would not refuse to acknowledge that its periodicity had been discovered by an Englishman. Nor has posterity attempted to deprive him of the honours which were his due; his discovery forms an epoch, and an important one, in the history of astronomy. His calculations must have been laborious in the extreme. He assures us himself they were 'prodigiously' long and troublesome; but the zeal which induced such an amount of exertion was well rewarded by the final result.

As the time of the comet's return drew nigh, the attention of astronomers was more particularly directed to the probable effects of the attraction of

Jupiter and Saturn, hinted at by Halley. The eminent French geometer, Clairault, investigated the theory which it would be necessary to apply in the numerical determination of the disturbances produced by these planets; and having devised a method which appeared to possess all needful accuracy, he commenced, in conjunction with the celebrated Lalande and a lady, Madame Lepaute, the immense mass of calculations requisite for the complete attainment of his object. It was necessary to compute the distances of the comet from the disturbing planets, Jupiter and Saturn, not only from 1682, when it was last observed, but for the previous revolution, or for a space of more than one hundred and fifty years. This of itself was a most laborious business; but the succeeding part of the work, where the disturbing force of each planet was required for this long period, involved much greater and more intricate calculations. Lalande minutely describes the plan adopted: for six months they computed from morning to night, with but little intermission, even, as he states, at meals; and he mentions, as one result of this assiduous attention to the work, that he contracted an illness which remained upon him during the rest of his life. Madame Lepaute's assistance is said to have been so important, that without it they would hardly have completed the investigation before the comet reappeared. However, by dint of these extraordinary exertions, the calculations were brought to a close; and on the 14th of November, Clairault announced to the French Academy of Sciences, as the principal results, that

the comet would be retarded by the action of Jupiter no less than five hundred and eighteen days, and one hundred by that of Saturn, making a delay of six hundred and eighteen days; and hence he predicted that the perihelion passage would take place on the 13th of April, 1759. In announcing this memorable conclusion, Clairault observed that he did so with some diffidence, because the small quantities unavoidably neglected in the calculations might possibly exercise an influence one way or the other to the amount of one month. Messier had been looking out for the comet during the whole of the year 1758, and many other astronomers searched the heavens for it, after the knowledge of Clairault's important results had reached them.

It was not destined, however, that a professed astronomer should be the first to obtain a glimpse of the wanderer on its return to visit these lower worlds. It was perceived on the night of December 25, 1758, by an amateur astronomer, named Palitzch, a farmer living at Prohlis, near Dresden, who saw it with his telescope of eight-feet focus, and not with the naked eye as frequently stated. The Baron de Zach was personally acquainted with this diligent observer of the heavens, and has corrected several mistakes respecting him. He possessed a strong sight, and was in the habit of examining the heavens with the naked eye, which has probably given rise to the statement of his having detected the comet without optical aid, at a time when all the astronomers in Europe were seeking for it with their telescopes without success. Palitzch saw the comet again on

the 26th of December; and on the 28th of the same month it was detected by Dr. Hoffman. An astronomer at Leipsic found it on the 18th of January. Messier was much interrupted by cloudy weather, but on the 21st he caught a glimpse of the comet, and observed it regularly for the three weeks following. Delisle, then director of the observatory at Paris, would not allow him to give notice to the astronomers of that city, that the long-expected body was in sight, and Messier remained the only observer before the comet was lost in the sun's rays. Such a discreditable and selfish concealment of an interesting discovery, is not likely to sully again the annals of astronomy. Some members of the French academy looked upon Messier's observations when published as forgeries, but his name stood too high for such imputations to last long, and the positions were soon received as authentic, and have been of great service in correcting the orbit of the comet at this return.

The inferior conjunction with the sun taking place about the end of February, the comet was too near that luminary to be visible before the last week in March. It was found again by La Nux, at the Isle of Bourbon, on the 26th, and by Messier on the 31st; and Delisle having withdrawn his interdict, the formal announcement of the reappearance of the comet was made on the 1st of April. Towards the end of this month, it again became invisible in Europe, owing to its low situation in the southern heavens, but in the meantime had been recognised and observed at Lisbon, Toulouse, Avignon, and other places. At the time that it was below the horizon in

Europe, observations were taken by La Nux, and by Father Cœurdoux, at Pondicherry. On April 28th, the comet was again found at Lisbon, and a few days afterwards at Paris, and at nearly all the observatories of Europe: this third appearance extended to June 3rd, when the comet was finally seen by Messier. Its aspect in 1759 was not so imposing in these parts of the world as some astronomers had anticipated, but this was mainly owing to its position near the vapours of the horizon, when it would otherwise have been most brilliant. In the southern hemisphere, however, it presented a fine appearance, the tail being not less than 47° long on the 5th of May, and very conspicuous for some time previous. The perihelion passage took place on the 12th of March, just one month before the time announced by Clairault: a closer coincidence could hardly have been expected, for the masses of Jupiter and Saturn were not accurately known at this epoch, and their perturbing forces could not therefore be exactly determined. Laplace has pointed out that the error, instead of amounting to thirty days, would not have exceeded thirteen, if the mass of Saturn had been as well known then as it is now.

Halley had departed this life at a good old age, eighteen years before the fulfilment of his prediction, but his name was universally associated with the comet whose return foretold by him had formed so memorable an epoch in the history of the science.

As the next and last reappearance of the comet drew nigh, several of the most eminent mathematicians of Europe undertook the calculation of the effects of

planetary attraction on the elements of the orbit, since the year 1759. The great advances which had been made in analysis since that period, and the more accurate knowledge of the masses of the disturbing planets, rendered the solution of the problem in the present case of almost equal interest with the labours of Clairault; nor were the expectations of a high degree of exactness in the prediction disappointed by the result. In 1817, the Academy of Sciences at Turin proposed the determination of the perturbations of Halley's comet since 1759, for their prize, which was to be open for competition to astronomers of all nations. The late Baron Damoiseau, of Paris, was the successful candidate: his researches are published in the memoirs of the Turin Academy, but we can only give the principal conclusion. After calculating the effects of the attraction of the larger planets upon the comet's mean motion from 1759, he fixed the ensuing return to perihelion, for the 4th of November, 1835, at eight P.M. Paris time. Some years afterwards, M. Pontecoulant, another eminent French geometer, investigated the problem again, and after applying some corrections to his first numbers, he announced as his final result, that the comet would reach its perihelion on November 12 that 17^h Paris time, or about a week later than the epoch assigned by Damoiseau. The most elaborate inquiry relative to the perturbations between 1759 and 1835, is, however, due to Professor Rosenberger, of Halle. Both Damoiseau and Pontecoulant had omitted the consideration of the influence of several of the planets, and had not fully investigated the exact period corresponding to the ellipse

described by the comet at its reappearance in 1759; this being the starting point and the foundation upon which much of the accuracy to be expected in the ultimate conclusions depended, it was evidently desirable to ascertain it with all possible precision. Rosenberger was therefore induced to commence his labours with a new computation of the perturbations between 1682 and 1759, having deduced elements from the observations of each of those years. He thus obtained a secure basis for the continuation of the work through the next revolution, between 1759 and 1835. Not to trouble the reader with more numerical results than are necessary, we shall be content with giving the most important deductions, premising that, besides the influence of the great planets, Jupiter, Saturn and Uranus, this distinguished mathematician included the smaller disturbances produced by Venus, the Earth and Mars, and also pointed out the probable effect upon the next perihelion passage, of a resisting medium in the planetary spaces, such as Professor Encke, of Berlin, had supposed to exist, from certain observed accelerations in successive returns of the periodical comet which bears his name. Omitting at first this latter consideration, the periodic time from 1759 to the next return was found to be 28002 days, and the perihelion was fixed for November 11th at 0h Paris time. With the computed effect of a resisting medium, this epoch would fall a week earlier, or on November 3rd at 19^h Paris time. The earth hastened the comet's perihelion passage $15\frac{3}{4}$ days, Venus about $5\frac{1}{3}$ days, and Mercury and Mars together nearly one day. Professor Rosenberger's investigation is remark-

able for its extraordinary completeness, for the pains taken to include every possible source of perturbation, without regard to the numerical labour, and for the masterly manner in which the whole of the vast work was conducted. Accordingly, astronomers generally have awarded him the palm for the most elaborate and valuable memoir upon this interesting subject. But we have yet to speak of another discussion of the elements and disturbances of the orbit of Halley's comet, by Dr. Lehmann, which, though inferior in several respects to Rosenberger's, has yet very great merit, particularly as regards the extension of the computations to the year 1607. The epoch fixed upon by this astronomer for the comet's arrival at perihelion was the 26th of November, a fortnight later than that announced by Pontecoulant or Rosenberger. The cause of this difference has been attributed to the want of a sufficiently minute attention to the effects of small but progressive changes in the elements between 1759 and 1835, in which matter however, we ought to observe, very much is left to arbitrary arrangement.

So early as December, 1834, astronomers began to direct their telescopes to that quarter of the heavens where the anxiously-expected wanderer was to reappear. Dr. Olbers, in an able paper published at the latter end of the same year, had given it as his opinion that the comet might possibly be discovered much sooner than was usually anticipated, and pointed out the track it should pursue in the heavens between December and April following, on two hypotheses as to the time of perihelion passage—viz., 1835, November

1st and 11th. He supported this opinion by an examination into the circumstances of its previous apparitions, and by adducing additional evidence founded on the brightness of other comets, particularly of one which appeared in 1811. A call to arms from this celebrated astronomer was not likely to meet with inattention. Many European observers sought diligently for the comet about the expected path in December and January, when the part of the heavens between Auriga and Taurus, where it should have been seen, was most favourably placed for examination, in a dark sky: all their efforts were in vain. Sir John Herschel, also, having received the calculated positions, employed his great reflector at the Cape of Good Hope in searching for the comet during the winter months, but no glimpse of it could be obtained. Similar "sweeps" over the suspicious neighbourhood in March and April following, were equally unavailing, and the reappearance of this region of the heavens, after conjunction with the sun about midsummer, was anxiously awaited. The first glimpse of the comet was obtained by Father Dumouchel and the astronomers of the Collegio Romano, at Rome, who, aided by their splendid climate and the powerful telescope of the observatory, succeeded in finding the welcome visitant on the morning of the 6th of August, close to the computed place, which at this time was in the neighbourhood of the star ζ Tauri. It was a faint, misty object, scarcely discernible with considerable optical power under an Italian sky. The presence of moonlight and unfavourable weather during the next fortnight, delayed the comet's

discovery at other places; but on the 21st, Professor Struve saw and observed it with the grand telescope at Dorpat, and within the ensuing week it was found by the astronomers of Vienna, Berlin, Kremsmünster, Altona, Breslau, and Leyden, as well as by Sir James South, Captain Smyth, and Dr. Hussey, in this country. According to the observation at Dorpat on August 20th, the error of Professor Rosenberger's predicted place was only seven minutes of arc in right ascension and seventeen minutes in declination, which, with succeeding observations, showed that the perihelion passage would be retarded till November 16th, or five days later than the epoch fixed upon by the above mathematician. During the first three weeks in September the comet gradually increased in brightness, but exhibited no indications of a tail. On the 23rd it was seen with the naked eye by Professor Struve, and on the following day by Kaiser at Leyden, though it was not sufficiently conspicuous to attract general attention until the end of the month. The first appearance of a tail is dated on September 24th. After the beginning of October the comet rapidly increased in brightness, and for the five weeks following was watched with the naked eye in its course through Ursa Major, Hercules, and Ophiuchus. The tail attained its maximum length about the middle of October, but, as in many previous instances, observers at stations widely distant differ very considerably in their estimation of its actual extent. On the 14th Struve says it was brilliant, and more than 20° long. Next evening it was 24° long at Breslau, and about 20° to M. Schwabe, at Dessau. On the 19th it was

traced fully 30° from the nucleus, at Madras, and only 15° on the 22nd. After this time it became gradually shorter, and, according to most accounts, had vanished entirely before the comet sank below the south-western horizon, about the time of perihelion passage. Köller continued his observations at Kremsmünster till November 22nd. From this date till the 30th of December the comet was hidden in the sun's rays, but was again detected by Kreil, at Milan, on the latter day, and observed at some of the more southerly observatories of Europe, and at the Cape of Good Hope, till the middle of May following, when this interesting object was finally lost to view, to return again to these parts of space in the year 1911, a reappearance which few of those who remember its last visit can expect to witness.

Some very extraordinary phenomena were observed by astronomers in the head of the comet, particularly by Professor Bessel, Sir John Herschel, and Professor Struve. The latter compares the appearance of the nucleus, about the end of the first week in October, to a fan-shaped flame, emanating from a bright point, and subsequently to a red-hot coal, of oblong form. On the 12th, says the same astronomer, its aspect was astonishing. It appeared like the stream of fire which issues from the cannon's mouth after discharge, when the sparks are driven backward by a violent wind. At moments, the flame was thought to be in motion, scintillations similar to those of the Aurora Borealis being suspected. A second small flame, forming a great angle with the principal one, was also remarked. On the 5th of November, the nebulosity

without the flames (two being visible) was shaped like a 'powder-horn'; its arched form is described as most remarkable. Phenomena of the same kind variously commented upon, under the names of luminous rays, sectors, &c., were observed by the other astronomers we have named, by M. Arago, at Paris, Mr. Cooper, at Markree Castle, and elsewhere. We shall content ourselves with referring the reader, who may wish for further information on the subject, to Struve's *Beobachtungen des Halleyschen Cometen*, Professor Bessel's Memoir in the *Connaissance des Temps* for 1839, the *Southern Observations* of Sir John Herschel, and to the *Memoirs of the Astronomical Society*, Vol. X., which contains several excellent drawings by Professor C. P. Smyth. The elements of the orbit of the comet at perihelion, in 1835, have been made the subject of a masterly investigation, by the late Hermann Westphalen, whose results will be found in the general table.

The dimensions of the path of Halley's comet in space, according to the latest calculations, are as follow :—

	In parts of the earth's mean distance.	In English miles.
Least or perihelion distance	0·5866	55,900,000
Greatest or aphelion distance	35·3660	3,370,300,000
Major axis of the orbit	35·9526	3,426,200,000
Minor axis of the orbit	9·1072	867,900,000

Thus, it will be seen that this body recedes from the sun, to a distance exceeding that of the planet Neptune. At the more remote parts of the orbit, it is always far removed from the plane of the ecliptic on

the south side. Its motion is in the contrary direction to that of the planetary system, or against the order of signs; and this fact is the more worthy of remark, inasmuch as it affords the only instance of a retrograde periodical comet, with which we are at present acquainted.

Before concluding our account of Halley's comet, we must briefly review its probable history prior to the year 1531, at which we took our departure.

In looking back into the history of comets, Halley found that one had appeared in 1456 which gave every indication of identity with the comet of 1682, and the celebrated French cometographer, Pingré, has converted Halley's suspicion into a certainty. It was seen in the month of June, and is described by the historians of the day as great, terrible, of extraordinary magnitude, 'training after it a tail which covered two celestial signs,' or was 60° in length. It was beheld with equal awe by the Turks under Mahomet II., and by the Papal forces, each regarding it as the omen of defeat and of divine displeasure. The nucleus shone like a star, and the tail presented a brilliant golden colour, at times assuming the appearance of a flame flickering to and fro. The comet was in perihelion, or nearest to the sun, on the 9th of June.

The preceding return of Halley's comet took place, as M. Laugier has shown, in the year 1378, when it was discovered both in Europe and in China, though it does not appear to have been so bright as in 1456. It arrived at perihelion on the 9th of November, and therefore followed a track amongst the stars not very

different from that pursued in the autumn of 1835. All the circumstances recorded of the comet of 1378 in the Chinese annals, are faithfully represented by the elements of Halley's comet.

In September, 1301, a great comet is mentioned by nearly all the historians of that period. It was seen as far north as Iceland, and is described also in the annals of China. It exhibited a bright and extensive tail, which stretched out from the west towards the eastern parts of the heavens. An anonymous author has left two contradictory observations, one of which cannot be reconciled with the elements of Halley's comet; but as the Chinese relation agrees extremely well with those elements, and this body was certainly due about 1301, it appears highly probable that it was really the object observed, the perihelion passage taking place about October 22nd.

The previous apparition is not so well ascertained, but most likely occurred in July, 1223, when it is recorded in an ancient chronicle, that a sign called a comet appeared in the heavens, shortly before the death of Philip Augustus of France, of which event it was generally considered the precursor. Unfortunately its position amongst the stars is not stated: we are only told it was visible in the western heavens in the evening twilight. The little that is related of it will agree very well with the elements of Halley's comet; and as no other is recorded about this year at all likely to have been the same as the one in question, it seems not improbable that our comet appeared in 1223, and reached its perihelion about July.

In April and May, 1145, a very great comet is mentioned by European historians, which continued visible a long time. The Chinese saw it towards the end of April, and describe it as of a pale blue colour, with a tail more than 10° long. The course amongst the stars from the end of April to the beginning of July, is perfectly in accordance with the computed track of Halley's comet, supposing the least distance from the sun to have been attained on the 19th of April. This is one of the most certain of our series of returns.

There is considerable probability in favour of the appearance of the comet in the year of the Norman Conquest, or in April, 1066. The famous body which astonished Europe in that year is minutely, though not very clearly, described in the Chinese annals, and its path there assigned is found to agree with elements which have great resemblance to those of Halley's comet. In England it was considered the forerunner of the victory of William of Normandy, and was beheld with universal dread. It was equal to the full moon in size, and its train, at first short, increased to a wonderful length. Almost every historian and writer of the eleventh century bears witness to the splendour of the comet of 1066, in which we are disposed to recognise the comet of Halley.

Burckhardt, the French mathematician, calculated an orbit for a comet observed in China in 989, closely resembling that of Halley's. The comet is mentioned by several Saxon chronologists, and by Elmacin, in his history of the Saracens. The perihelion occurred on the 12th of September.

Another comet recorded by the Chinese in May and June, 837, and probably seen in Europe, affords some indications of identity The perihelion would fall about the beginning of April. This great body must have been a different one from Halley's, if all the accounts, European and Chinese, can be strictly relied upon.

The preceding apparition is referred by M. Laugier to the year 760, and is well certified by the annals of China. The historians of the western empire tell us that a comet like a great beam and very brilliant was observed in the 20th year of Constantine, first in the eastern heavens, and subsequently in the west for about thirty days. In China it was seen two months. It is assumed that Halley's comet arrived at its least distance from the sun on June 11th, and every particular is exactly represented by the elements of that body. The appearance of our comet in 760, is a matter little short of a certainty.

In 684, Ma-tuan-lin, the Chinese historian, has mention of a comet which was observed in the western heavens, in September and October. This will agree with the course of Halley's, when its perihelion passage falls about the middle of the latter month; and as the interval agrees well, we may infer that there is a fair probability in favour of the identity of the comets.

We are disposed to recognise Halley's star, again, in the comet observed by the Chinese in the constellations Auriga, Ursa Major, and Scorpio, in 608; this being precisely the track of that body if it attained its least distance from the sun about November 1st.

The apparition which should have occurred about 530 is not well ascertained. It may be remarked, that a great comet recorded by the Latin authors in that year, which was visible, in the western sky, in Ursa Major, offers nothing contradictory to its identity with Halley's, and, in fact, the few circumstances related of it agree much better with the elements of Halley's comet than with those of the great comet of 1680, which many astronomers have regarded as the same that appeared in 530, or 531—for some doubt exists respecting the year of appearance.

We have pretty decisive evidence in favour of the return of the comet in 451, as M. Laugier has shown. It was seen in Europe about the time of the Battle of Chalons, when the Roman general, Aetius, obtained a victory over the armies of Attila, whose ravages had extended to France. The Chinese discovered it on the 17th of May, and followed it on its course till the middle of July, in which interval it had moved from the Pleiades into Leo and Virgo. The circumstances agree well with the track of Halley's comet, assumed to have been in perihelion on July 3rd.

In October 373, the annals of China mention a comet in Ophiuchus, which will agree with the position of the same body, if we fix its arrival at the least distance from the sun about the beginning of November.

In 295, the appearance of this comet is nearly certain: it was observed in China in the fourth moon during its progress from Andromeda into Virgo. The perihelion passage would take place at the commencement of April.

There can be little doubt of another return in the year 218, when we have a circumstantial account of a large comet in the catalogue of Ma-tuan-lin, which followed a path exactly in agreement with that of Halley's, when the perihelion falls on or about April 6th. It is mentioned by Dion Cassius, who describes it as a very fearful star, extending its tail from the west eastwards. The comet this year traversed the constellations Auriga, Gemini, Leo, and Virgo.

In 141, the Chinese observed a comet, the track of which in the heavens may be represented by elements not very widely different from those of Halley's; it is the only comet recorded about this epoch.

The preceding apparition took place either in the summer of the year 65, or early in 66. Two Comets are found in the Chinese annals. That of 65 was discovered in July, in the constellation Leo, and continued visible fifty-six days. The second was seen in February following, in Sagittarius and Scorpio, and remained in sight fifty days. This latter body appears most likely to have been Halley's, if the perihelion occurred on January 26th. But it is possible this comet may have appeared in 65, in which case it was not improbably the sword-shaped sign over the city of Jerusalem, recorded as having preceded the commencement of the war which terminated in the destruction of the holy city.

In the year 11 B.C., during the consulate of M. Valerius Messala and P. Sulpicius Quirinus, before the death of Agrippa, a comet is referred to by Dion Cassius, which seemed to be suspended over the city

of Rome. The same comet was very closely observed by the Chinese, whose valuable details respecting its path amongst the constellations afford the most satisfactory proof that they belong to the comet of Halley. It passed from Gemini, through Leo, Bootes, Hercules, Ophiuchus, into Scorpio, where it was lost in the sun's rays, fifty-six days after its first discovery. It was in perihelion in the third week of October.

Previous to the year 11 B.C., the Chinese descriptions of comets are too vague to aid us in tracing any more ancient appearances of Halley's comet, and European writers of these remote times render us no assistance. The series of returns which we have briefly pointed out is most satisfactory as a whole. That of 1456 was known to Halley, and the appearances of 1378, 760, and 451, were recognised by M. Laugier some years since; with these exceptions, the whole of the probable returns of the comet prior to 1531 were notified in a paper by the author, which was read before the Royal Astronomical Society, in January, 1850.*

The following is a tabular view of the most probable epochs of perihelion passage. The reader will understand that much uncertainty attaches to the result in one or two cases, but the series seems hardly to admit of doubt as to its *general* accuracy. The most certain appearances previous to 1456 are marked with an asterisk; and to render the table complete, the perihelion passages are added down to the year 1835.

* See Monthly Notices of the Astronomical Society, vol. x., No. 3

The epoch of perihelion passage is expressed in years and decimals. The intervals indicate the length of each revolution.

Year.	Interval.	Year.	Interval.
	YRS.	A.D.	YRS.
A.C.*11·80		989·70	
	77·87		76·55
A.D. 66·07		1066·25	
	75·17		79·05
141·24		*1145·30	
	77·20		78·22
*218·26		1223·52	
	76·99		78·29
*295·25		1301·81	
	78·59		77·04
373·84		*1378·85	
	77·66		77·59
*451·50		1456·44	
	79·34		75·21
530·84		1531·65 (O. S.)	
	77·96		76·14
608·80		1607·82 (N. S.)	
	76·00		74·88
684·80		1682·70	
	75·64		76·49
*760·44		1759·19	
	76·82		76·68
837·26		1835·87	
	74·99		
912·25			
	77·45		

CHAPTER V.

COMETS OF SHORT PERIOD—THE COMET OF ENCKE.

THE most remarkable of the comets of short period is that known as ENCKE'S; it is a body of the highest interest to the astronomer, and we shall here recapitulate briefly the principal points in its history.

On the 17th of January, 1786, M. Mechain, of Paris, discovered a telescopic comet, near the star β, Aquarii. It was pretty large and bright, with a sensible nucleus surrounded by nebulosity, but without any appearance of a tail. Cloudy weather prevented M. Mechain from observing it, except on January 17th and 19th; so that no orbit could be deduced from observation.

Miss Caroline Herschel, sister of the celebrated Sir W. Herschel, detected a comet not far from the star marked γ in Cygnus, on the 7th of November, 1795. It was just visible to the naked eye: in the telescope no nucleus was perceptible, but merely a condensation of the nebulous matter near the centre. The comet was observed at Berlin, by Professor Bode, on the 11th of November, an amateur astronomer named Carl having announced its visibility; and on the 14th, M. Bouvard saw it at Paris. The outline of the nebulosity is

described as nearly if not quite circular, the greatest apparent diameter amounting to about five minutes of space on the day of discovery. The elements were investigated, on the assumption of parabolic motion, by Dr. Olbers, M. Bouvard, and Baron de Zach.

On the evening of the 20th of October, 1805, a comet was found, almost simultaneously, by M. Pons at Marseilles, Professor Huth at Frankfort, and M. Bouvard at Paris. It was situate in Ursa Major. The perihelion passage occurred about a month after the discovery, and the comet was observed until within a week from this epoch. The parabolic orbit was calculated by MM. Bouvard and Legendre, and Professors Bessel and Gauss.

M. Pons, of Marseilles, a most industrious observer, detected a telescopic comet on the 26th of November, 1818, which remained visible till the 12th of January following. It was speedily found that no parabolic orbit could be made to represent the observations within their probable limits of error, and this circumstance induced the celebrated calculator, Professor Encke, to undertake the rigorous investigation of the elements. On treating the observations agreeably to the methods of Professor Gauss (but little practised at that time), a most important result was obtained. Professor Encke showed that the real path of the comet must be an ellipse, with a period of about three years and a quarter; and on looking over the catalogue of comets already observed, it appeared highly probable that the one in question had been previously seen, and was, in fact, identical with the comets of 1786, 1795, and 1805, those years agreeing

well with the presumed time of revolution of the comet of 1819. The question could only be definitely settled by calculating the planetary perturbations backward to the respective epochs; and this enormous labour was entered upon by Professor Encke, and completed in the most masterly manner, after close application for about six weeks. It was found that the comet had arrived at perihelion on January 30th, 1786; May 19th, 1789; September 4th, 1792; December 21st, 1795; April 11th, 1799; August 2d, 1802; November 22d, 1805; March 12th, 1809; June 26th, 1812; October 13th, 1815; and again on January 27th, 1819. In 1789, 1792, 1799, 1802, 1809, 1812, and 1815, it passed through these parts of space without being detected by any observer. The average time of revolution appeared to be about 1208 days; but on allowing for the perturbations of Jupiter, the period still exhibited indications of a gradual diminution since the year 1786, unaccounted for by the disturbances produced by other planets, and too large to be attributed to the effect of any quantities omitted in the calculation. On this interesting point we shall have more to say very shortly.

After having thus brought to light the past history of the comet, at the expense of a vast amount of labour, Professor Encke turned his attention to the next return to perihelion, and again undertook the determination of the perturbations produced by planetary attraction on the movements of the comet. He announced, as the principal result of his investigations, that the comet would arrive at perihelion on the 24th of May, 1822, after undergoing a retardation of rather

more than nine days from the influence of the planet Jupiter. So complete were these calculations that astronomers universally attached the name of ENCKE to the comet of 1819, not only as an acknowledgment of his diligence and success in the performance of some of the most intricate and laborious computations that occur in practical astronomy, but also to mark the epoch of the first detection of a comet of short period, one of no ordinary importance in this department of the science.

Owing to the position of the comet in the heavens about the time of perihelion passage in 1822, it was not seen at all in Europe, but there fortunately existed an observatory in full activity at Paramatta, New South Wales, founded and maintained by the munificence of a private individual, Sir Thomas Brisbane, then Governor of the colony. Mr. Rümker, the present director of the observatory at Hamburg, detected the comet at Paramatta on the 2nd of June, and followed it until the 23rd of that month. His observations enabled Professor Encke to rectify the elements, and predict the time of its next arrival at perihelion with the greater accuracy. He found it should occur on the 16th of September, 1825, and that the apparent path of the comet in the heavens would allow of observations at the European observatories.

Professor Harding, the discoverer of Juno, obtained the first glimpse of the wanderer on the 26th of July, 1825, in a position differing from the predicted one by less than three minutes of space. The comet was observed at nearly all the astronomical

establishments of Europe until about ten days before the perihelion, when it was lost in the sun's rays. It appeared round and very bright towards the centre, and it was remarked by Professor Argelander in the strong twilight as a small planetary disk, with scarcely any signs of the surrounding nebulosity.

The next return of the comet, in 1828, excited great interest, as, for the first time since the discovery of its periodicity, the apparent track amongst the stars would be peculiarly favourable to observation in Europe. The epoch of perihelion passage was fixed by Encke on the morning of the 10th of January, 1829. Professor Struve, employing the magnificent telescope then newly erected at Dorpat by the Emperor of Russia, saw the comet as a very faint nebulosity on the 16th of September, 1828. At Berlin it was seen by MM. Kunowsky and Encke with a much smaller instrument on the 7th, but it was not generally observed until the end of the month.

On November 30th it was visible to the naked eye as a conspicuous star of the sixth magnitude, and a week afterwards was still brighter, so as to be rated with stars of the fifth class. The outline of the nebulosity was not circular, but somewhat elliptical, the major axis, on one occasion, being nearly at right angles to the line joining the sun and comet, which is the usual direction of the tails of these bodies. The angle of position of the longer axis of the elliptic comet in respect to the circle of declination, and counted from the north towards the west, was measured on four evenings by Professor Struve, and on comparing it with the direction of the line joining the sun and

comet, he ascertained that the major axis of the comet made the following angles with the radius-vector on the respective days:—

Nov. 7 - -	99°·7	Dec. 7 - -	154°·0
Nov. 30 - -	145°·3	Dec. 14 - -	149°·4

The comet was seen at Dorpat and Nismes, until the close of the year 1828, when its gradual approach to the sun's place rendered it invisible.

The next return to perihelion took place in 1832, the calculations of Professor Encke assigning the 4th of May as the epoch of the comet's arrival at its least distance from the sun. The path in the heavens was again unfavourable to observation in Europe, and only a single glimpse of the wanderer was obtained by Harding, at Göttingen, on the 21st of August. It was, however, found by Mr. Henderson, at the Cape of Good Hope, and by M. Mossotti, at Buenos Ayres, at the beginning of June, and their observations were discussed by Professor Encke in a memoir communicated to the Prussian Academy of Sciences, in 1834.

As the observations of 1832 afforded no satisfactory foundation for any further correction of the elliptic elements, they were carried forward to 1835 by simply taking account of the perturbations produced by the planet Jupiter, which was never very near the comet. The perihelion passage was fixed for the evening of the 26th of August, and notwithstanding the difficulties attending observation, owing to the position of the comet amongst the stars, it was seen after the 26th of July by M. Kreil, at Milan, and Professor Bogus-

lawski at Breslau. Mr. Maclear saw it at the Cape of Good Hope, on September 14th, and on two other occasions, with a 14-feet reflecting telescope, constructed by Sir W. Herschel, but no measures could be taken. It looked as he had seen it in England.

The next visit in 1838 was predicted to take place under circumstances particularly favourable to European observers. The comet was discovered with the fine refractor at Berlin, on the 16th of September, and by the Rev. W. R. Dawes, with a 5-feet telescope, at Ormskirk, on the 27th of the same month. With these exceptions it was not observed until the middle of October. The least distance of the comet from the earth was 0·22, and about the end of the first week in November this interesting object could be discerned in the constellation Draco without the assistance of a telescope. When viewed under suitable optical aid, it was found to exhibit a bright nuclear condensation, from which the nebulosity streamed off in a fan-like form, the general outline of the whole being that of a broad parabola. On the 7th of November it was described as a very splendid object, the light being particularly intense and glowing. M. Valz saw it until the middle of December.

After the publication of the observations taken at the various observatories of Europe in 1838, a most elaborate discussion of the elements was entered upon by Professor Encke, to whom astronomers had been hitherto indebted for their information respecting this comet's returns. One important object of research was, the determination of the mass of the planet Mercury, near which the comet had passed in August,

1835. It had been shown by Encke that if Laplace's mass were correct, the effect of the planet's attraction would diminish the geocentric right ascension of the comet on November 2nd, 1838, no less than 58′, while the declination would be increased 17′. The observations not having indicated any such enormous deviation from the elliptic path, it became evident that a very large error existed in the received mass of the planet; and it was obviously rather a matter of labour, than difficulty, to deduce from the observations of 1838 a more exact value of that element. The mode of procedure was, to calculate with the utmost nicety the amount of perturbation produced by each of the planets, employing the best values of the masses extant. Then, were there no other cause operating to affect the geocentric positions, the differences between the places rigorously computed from the elements after a consideration of the other planetary disturbances, supposed to be *exactly* known, and those given by the observations, would be due to any error in the presumed attraction of the planet Mercury, and from these numbers the alteration required to bring about a perfect agreement between observation and calculation could be inferred. But it so happened, that another influential disturbing agency was present, the existence of which Professor Encke had already intimated as extremely probable, and without which there appeared no way of accounting for an acceleration in the times of arrival at perihelion between 1819 and 1838, over and beyond the epochs determined by his researches into the effects of planetary attraction. The comet had been

remarked to reach the point of least distance from the sun, at each return, about 2h. 30m. sooner than the time assigned by the calculation. In order to account for this gradual diminution of the period of revolution, Professor Encke supposed that a thin etherial medium pervades the planetary spaces, sufficiently dense, however, to produce some impression on a body of such extreme tenuity as the comet in question, but incapable of exercising any sensible influence on the movements of the planets. This supposition has been converted almost into a certainty by the results of more recent observation and calculation, and has received the support of the first authorities of the present day. The great difference between the effects of such a medium on the comets of Encke and on the planets, will be evident from what has been stated respecting the pellucid and almost etherial nature of the former.

It may appear paradoxical at first sight that a medium tending to retard the velocity of the comet's orbital motion should ultimately accelerate its return to perihelion. But this resistance to the comet's movement at any point of the trajectory has the effect of increasing the sun's attraction, and consequently of drawing the comet into a smaller orbit than before: the length of the major axis is therefore diminished, and the period of revolution shortened in proportion. This contraction of the orbit must be continually progressing, if we suppose the existence of such a medium, and we are naturally led to inquire what will be the final consequence of this resistance? Though the catastrophe may be averted for many

ages by the powerful attractions of the larger planets, particularly Jupiter, will not the comet be at last precipitated on to the sun? The question is full of interest, though widely open to conjecture.

The *constant of resistance*, as it is termed by Professor Encke, was not definitively settled previous to 1838, and it therefore became necessary, for the complete solution of the problem, to regard it as a quantity only approximately known, and so leave it open for more exact determination from the observations of 1838. The differences between the observed and computed positions in that year were therefore considered due to the corrections required—first, in the assumed mass of Mercury, and, secondly, in the constant of resistance; and by treating these quantities agreeably to methods commonly practised amongst astronomers, it was found as the principal result that the planet's mass assigned in the *Mécanique Celeste* of Laplace was far too great, or that it required to be diminished in the proportion of seven to twelve. Thus has a body of such apparent insignificance as Encke's comet enlightened us on more than one point of the highest astronomical interest.

The elaborate discussion of the elements to which allusion has been made, appeared in Nos. 488-9 of the *Astronomische Nachrichten*, and the numbers there obtained have been used as the foundation for all subsequent prediction. The comet was expected to become visible again early in 1842, and to reach the perihelion point on April 12th. It was found by Dr. Galle at Berlin, on the 8th of February, and observed

pretty generally in Europe until the 10th or 11th of April. It was found, on its return from the sun, at the observatory, Cape of Good Hope, on May 2nd, and continued visible there for three weeks. It is generally described as round, bright, and so well defined, as almost to exhibit a planetary disc. This agrees with Professor Argelander's description of the comet's appearance in 1825. The strong evening twilight doubtless hid a great portion of the more feeble nebulosity surrounding the nucleus, only permitting the denser part in the immediate vicinity of the comet's centre to remain visible. The real diameter of this condensed portion appears to have been about 25,000 miles.

The next appearance in the summer of 1845, took place under the most unfavourable circumstances; nevertheless, a very accurately computed ephemeris of its geocentric path was published by M. d'Arrest, of Berlin. Though the attention of astronomers was closely directed to the comet, it was seen in Europe by one observer only, the late Professor de Vico, who, favoured by the clear sky of Rome, observed it on the nights of July 9th and 14th. In America, two observations were procured, the first at Philadelphia, on the 4th, and the second at Washington, on the 10th of the same month. The error of the predicted place was less than 45 seconds of space, a most satisfactory proof that the theory of the comet's movements was well understood.

The next return occurred in the autumn of 1848, when its apparent track in the heavens was such as to allow of extensive observation in these parts of the

globe. The comet arrived at perihelion only five days later than in 1805, so that its path amongst the stars was not very different in the two years, and, judging from previous experience, Prof. Encke considered there would be little chance of any exact observations before the commencement of September. It was found by Professor Bond, with the great telescope, at Cambridge U. S., on the 27th of August, and by several astronomers during the first week of September. It was last seen by Professor Bond, on the 26th of November. When first visible in large telescopes, it was faint and without any condensation of light. On September 24th, the nebulosity extended over eight minutes of arc, or about 140,000 miles. Two days later, a faint brush of light extending from the more condensed part *towards* the sun, was detected by Professor Bond, and on the 6th of the following month, the same observer found it just visible to the naked eye. On the 22nd it was still distinctly visible without the telescope: the general outline was elliptical, and the light appeared strongest on the side opposite the sun. Early in November, the comet exhibited a tail in the usual direction, extending over a space of between one and two degrees, while the same emanation from the head *towards* the sun, that had been remarked in September, was again observed. The last observation of the American astronomer, on November 26th, was taken after a very close approach to the planet Mercury. About midnight, on the 22nd of that month, the comet was separated from the planet, by only 0·038 of the earth's mean distance, or 3,600,000 miles, a

much nearer approximation than that of August, 1835, from the effects of which the mass of Mercury at present received, was investigated. The observations of 1852, and subsequent years, will, therefore, lead to a more correct value of this element, for they will contain in them, the effects of the planet's perturbations, expressed as the mathematician can read them on the comet's geocentric places.

The last perihelion passage occurred on March 14th, 1852, and the comet was seen in the second week of January, and remained visible two months. Early in March, it was very distinct in the strong evening twilight. Its appearance, when best seen this year, was similar to that presented in 1845; it resembled a nebulous star, with something of a planetary disc. In 1858, the track of the comet amongst the stars will be more favourable for observation than it was in 1852, or is likely to be in 1855.

The dimensions of the orbit of Encke's comet are as follow:—

	In parts of the earth's mean distance.	In English miles.
Aphelion distance	4·0927	390,010,000
Perihelion distance	0·3370	32,120,000
Minor axis	2·3489	223,840,000

Corresponding period of revolution 3·296 years.

CHAPTER VI.

COMETS OF SHORT PERIOD—*continued.*

The Comet of Biela.

ANOTHER very remarkable periodical comet is that usually called BIELA'S, though it has occasionally been termed Gambart's comet.

On the 8th of March 1772, M. Montaigne of Limoges, discovered a comet in Eridanus which he saw until the 20th of the same month, though for want of proper instruments he could observe it but very imperfectly.

M. Pons discovered a telescopic comet on the 10th of November, 1805, which was observed until the 9th of the following month. The elements very much resembled those of the comet of 1732, and the identity was hinted at by several astronomers, including Olbers and Gauss. The latter remarked that an ellipse with the greater semi-axis = 2·82 or longer, would agree better with the observations than a parabola, and his last calculation assigned as the most probable period 1732 days. Notwithstanding this circumstance it does not appear that any prediction of the return of the comet was ventured upon, and

the question remained in this state until 1826, when an unexpected discovery again drew attention to the subject.

On the evening of the 27th of February, 1826, M. Biela, of Josephstadt in Bohemia, detected a telescopic comet in the constellation Aries. It presented a small round nebulosity, with a feeble condensation of light towards the centre. The same comet was recognised independently by M. Gambart at Marseilles on the 9th of March, when it was situate in Cetus: there was no trace of tail or nucleus, and the diameter did not exceed $1\frac{1}{2}'$. It was very soon found that the elements bore a striking similarity to those of the comets of 1772 and 1805, and what was more important, that no parabolic orbit would represent with reasonable accuracy the observed path of the comet. Clausen, Biela, and Gambart, determined the elements of elliptic orbits, the period differing but little from 6·7 years. The identity of the comets of 1772, 1805, and 1826, was therefore rendered extremely probable, notwithstanding some calculations by the late Professor Bessel, which appeared to throw a degree of uncertainty on this conclusion, as respects the former year: but as we have already remarked, the comet of 1772 was very imperfectly observed, and was only followed by M. Montaigne during a space of twelve days.

Supposing the period of revolution about $6\frac{3}{4}$ years, the comet must have appeared in 1778, 1785, 1792, 1799, 1813, and 1819, without being perceived, and such was no doubt the case, for the computations of MM. Clausen, Gambart, and others, showed that the

period could not differ much from 2440 days, and that an ellipse with a major axis corresponding to this time, would represent equally well the observations of 1805 and 1826.

The comet of 1826 was observed by Dr. Olbers and M. Gambart until the end of April. It is generally described as a small circular nebulosity, destitute of tail or nucleus, and a very little brighter towards the centre than at the edges. Soon after the disappearance of the comet, Professor Santini, of Padua, undertook the determination of the effects of planetary disturbances on the ensuing return. He ascertained that the most probable value of the periodic time in 1826 was 2455·176 days and that the comet had arrived at its perihelion point on March 18th, at ten P.M., Paris time. He then calculated the amount of perturbation due to the attraction of the Earth, Jupiter, and Saturn, and found that the next revolution would be shortened 10·023 days by their combined influence, so that the comet should again arrive at perihelion about two o'clock on the morning of the 27th of November, 1832. The Baron Damoiseau also entered upon a similar investigation, and was led to infer that the return of the comet would be accelerated by 9·664 days, a result not very widely differing from that of Professor Santini.

In a paper by Dr. Olbers, published at the beginning of the year 1828, the attention of astronomers was directed to the very close approach of the orbits of the earth and comet at the descending node of the latter. In 1805 and 1826 the radius-vector of the comet at the nodal passage was greater than the

earth's, and consequently it passed *outside* our orbit. But in 1832 Dr. Olbers found that the comet at this moment would be nearer the sun than the earth, and would therefore pass inside our annual path, but at a distance from it of only 0·00033, or less than five terrestrial semi-diameters. Now, on the 8th of December, 1805, when the comet of Biela was near the earth, Dr. Olbers found the apparent diameter subtended an angle of 40′, whence he concluded that the real semi-diameter of the nebulosity was at least 5·25 radii of the earth, and it thus appeared certain that if the extent of the cometic atmosphere in 1832 were as great as in 1805, and if Damoiseau's calculations were rigorously accurate, a portion of the earth's orbit would be *within the nebulosity of the comet* at the nodal passage in 1832. The orbital arc, or arc of true anomaly between the descending node and perihelion amounted to 41° 45′, which the comet would require 29·0 days to traverse, and as the calculations had fixed the arrival at perihelion about midnight on the 27th of November, it was thus inferred that the passage through the descending node would take place on the evening of the 29th of October. The heliocentric longitude of the point of the comet's orbit which lies nearest that of the earth is 68° 10′, and the earth could not reach this point until the morning of the 30th of November, or one month after the comet's passage by it. These results, of course, showed that there was no ground for alarm, at least in 1832, as the two bodies would pass through the dangerous neighbourhood so long after each other. If the perihelion passage had occurred at eight P.M. on the 28th

of December, an extremely near approach, if not a collision, of the earth and comet must have taken place on the last day of November.

Though astronomers were satisfied the comet would not approach within many millions of miles from the earth, it was not so with the general public. Considerable alarm was excited on the continent as soon as Olbers' results were known, and the comet of 1832 was even anticipated as the destined agent in the destruction of our globe. It was argued that if a retardation of about one month in the arrival at perihelion should take place, the most disastrous consequences must follow—a line of reasoning which, though possibly correct in itself, was altogether inadmissible under the circumstances. The periodic time corresponding to the ellipse actually described by the comet at its visit in 1826 was known, without a greater error than one day, and the effect of planetary attraction had also been determined with all requisite accuracy. The date fixed for the perihelion passage, November 27th, could not therefore be well subject to a larger error than one day at the utmost. All fear of collision or dangerous proximity was evidently groundless.

The first glimpse of the comet at its reappearance was obtained by the observers of the Collegio Romano at Rome, on the 23rd of August. It was observed by Sir John Herschel, with his twenty-feet reflector, at Slough, on the 23rd of September, but at this time neither Professor Harding, with a 10-feet reflecting telescope, nor M. Nicolai with a 4½-feet achromatic, by the celebrated Fraunhofer, could dis-

tinguish it. The excessive faintness of the comet may be readily conceived. About the end of the third week in October it became more generally visible, and was last seen at the Cape of Good Hope, on the 3rd of January, 1833. It was always faint, with but little central condensation, and was at no time perceptible without a good telescope. The comet arrived at perihelion only twelve hours before the computed time,—a much closer fulfilment of prediction than could have been expected. Professor Santini, on a revision of his calculations, and after allowing for the attraction of Venus and Mars, which he had previously neglected, ascertained that the time elapsed between the perihelion passages of 1826 and 1832, was 2444·7027 days, his earlier computations having given 2445·1528 days. He then investigated the effects of planetary disturbances on the ensuing appearance, and found it would retard the comet $1^d\ 17^h$, so that the perihelion passage would occur on the 23rd of July, 1839, about noon, Greenwich mean time. The longitude of the comet in perihelion, as seen from the sun, is 110°, which differs only 10° from the geocentric longitude of the sun on the 23rd of July; and the comet's motion being direct, it is always too near this luminary to be easily detected when the perihelion takes place about this time. It passed through these parts of space in 1839 without being perceived in any part of the earth, and the next return, in 1846, was therefore anticipated with the greater interest. The calculations of Professor Santini, to whom we are indebted for nearly the whole of our knowledge of the comet's movements since 1826, indicated an acce-

leration of the ensuing arrival at perihelion by 31·884 days, the influence of the planet Jupiter being very considerable, not only on the periodic time, but likewise on the inclination of the plane of the orbit to that of the ecliptic, which was diminished 37′ in the interval between 1839 and 1846. The perihelion passage was fixed for about nine p.m. Greenwich time, on the 11th of February, 1846, and it was found the comet would remain visible a long time, and thus afford an opportunity of correcting the theory of its motion, by long-continued observation.

The powerful telescopes which are now happily found in many of the European observatories were employed in the search for the wanderer, as the time of its return drew near. It was discovered the same evening, November 28th, by Professor Encke at Berlin, and Signor De Vico at Rome; Professor Challis saw it on the 1st of December with the great Northumberland telescope at Cambridge, but it was not generally recognised till the third week in December, and was last seen on the 27th of April at the observatory of Bonn.

A phenomenon which created no little astonishment amongst astronomers, took place at this reappearance of Biela's comet. When it first became visible in the large refractors of Berlin, Cambridge, &c., it presented a faint nebulosity, almost if not perfectly circular in form, with but slight condensation towards the centre. On the 19th of December it was remarked to be somewhat elongated or pear-shaped, but this circumstance merely induced a passing notice, such distortions being not unfrequently noticed in telescopic

comets. Within a fortnight of this date, however, the comet had actually separated into two distinct nebulosities, which travelled along in company for more than three months. The circumstance was remarked independently by various astronomers, but the division appears to have been first perceived in America on the 29th of December. At the end of January and until the end of March the two comets were very generally observed: Mr. Otto Struve thought he could just distinguish the companion on the 16th of April, when the principal comet was observed for the last time with the great Equatorial at Pulkova. The apparent distance between the centres of the two nebulosities was at first little more than two minutes, but subsequently it increased to about seven times that quantity, and each head or comet exhibited a short tail in the usual direction, while something very like a stellar point was observable in each. The companion comet was even the brighter of the two about the 12th of February, but did not continue so more than three or four days. The real distance between the comets has been calculated by Professor Plantamour for different days: we subjoin some of his results, expressed in English miles, instead of semi-diameters of our globe :—

1846.		Miles.
February	10	149,800
February	17	153,560
February	26	156,660
March	3	157,240
March	16	155,770
March	22	154,200

The maximum distance attained on the 3rd of

March was therefore about two-thirds of the moon's mean distance from the earth. The angle of position of the line joining the two heads in respect to a fixed point, altered very little, according to Professor Plantamour's researches.

Biela's comet reappeared at the end of August, 1852, and continued visible about three weeks. Professor Secchi, of Rome, detected, on September 16th, a fainter comet near the above, which it preceded by two minutes of time in right ascension, being 30′ south. This object was considered to be, in all probability, the second part of the chief comet; and, if so, it had evidently become a distinct body, since its real distance from the other must have exceeded 1,250,000 miles. The morning twilight greatly interfered with observations this year.

The dimensions of the orbit of Biela's comet in 1846 were as subjoined:—

	In parts of the earth's mean distance.	In English miles
Aphelion distance	6·1926	590,100,000
Perihelion distance	0·8564	81,600,000
Minor Axis	4·6060	438,900,000

The corresponding time of revolution is 6·617 years.

CHAPTER VII.

OTHER COMETS OF SHORT PERIOD—FAYE'S, DE VICO'S, BRORSEN'S, D'ARREST'S.

The Periodical Comet of Faye.

NEARLY a quarter of a century after the discovery of the periodicity of Encke's comet, another object of great interest was brought to light by M. Faye, one of the astronomers attached to the Observatory of Paris. On the 22nd of November, 1843, he detected a telescopic comet in the northern part of the constellation Orion, which was visible till the 10th of April following. It exhibited a bright star-like nucleus, with a short, fan-shaped tail, in the usual direction, but was never bright enough to be discovered without optical aid. The incompatibility of the track which the comet was pursuing with the assumption of parabolic motion, appears to have been independently remarked about the same time by Professor Argelander of Bonn, Dr. Goldschmidt of Göttingen, and Professor Henderson, late director of the Royal Observatory at Edinburgh, who occupied themselves in the investigation of the true curve described by the comet. This was speedily found to be an ellipse, with a period of revolution of about 7½ years, or rather

longer than in the case of Biela's comet. A good deal of speculation followed with regard to the identity of the new comet with one observed by Messier in 1770, which was known to have suffered enormous perturbations through the attraction of Jupiter. The question was not set at rest till after the appearance of a complete memoir on the subject, by M. Leverrier, who, in tracing the past history of the comet of Faye, has proved that it could not have been the same as that of 1770, designated the 'lost comet;' but it must, notwithstanding, have been a denizen of our system for at least ninety-six years previous to its discovery by Faye. It is possible that in its descent towards the sun in 1747, when it passed close to the planet Jupiter, the action of this vast globe may have deflected the comet into its present orbit, and this is the least remote period at which disturbances to the amount necessary to produce a great change could have occurred.

M. Le Verrier predicted that Faye's comet would again reach its perihelion on the 3rd of April, 1851, at midnight, but its path amongst the stars would not be so favourable for observations in Europe as at the previous appearance. True to the prediction, the comet was in sight with the large telescope under the direction of Professor Challis, at Cambridge, and actually attained its least distance from the sun at the very hour named by the French mathematician some years beforehand, having suffered a retardation of between seven and eight days, chiefly through the influence of Jupiter, as M. Le Verrier had calculated. The exact length of the comet's revolution in 1843 was

2,718 days, and the elements necessary to construct the orbit at that epoch are as subjoined :—

	In parts of earth's mean distance.	In English miles.
Aphelion distance	5·9310	565,200,000
Perihelion distance	1·6926	161,300,000
Minor axis	6·3368	603,880,000

The other elements will be found in the catalogue of orbits (1843, III.)

The comet of Faye may be expected to arrive at perihelion again in October, 1858.

The Periodical Comet of De Vico.

On the 22nd of August, 1844, Father de Vico discovered a telescopic comet at the Collegio Romano at Rome, which continued visible in powerful telescopes until the end of the year. About the third week in September it was just discernible with the naked eye, and under slight optical aid had a very beautiful appearance, the nucleus being bright and star-like, and a short tail of a bluish tinge, extending in the direction opposite that of the sun. It was soon found by M. Faye and others that the observations would not agree with the assumption of parabolic motion, and on investigating the real nature of the conic section described by the comet it was ascertained to be an ellipse with a periodic time of about five and a half years. The elements have been calculated by Dr. Brünnow, with due regard to the influence of planetary attraction during the interval over which the observations extend, and his results show that at the time of perihelion passage the length of the comet's

revolution was 1993 days. The same computer has carried on the inquiry to the return in the spring of 1850, but it happened very unfortunately that when the comet was near enough to the earth to be otherwise discerned, it was always lost in the sun's rays, the geocentric positions of the sun and comet at perihelion being nearly the same, and continuing so for some months, on account of the apparent direct movement of both bodies.

At the next visit, in the summer of 1855, the comet will be more favourably located in the heavens, and astronomers will look forward with some interest to this re-appearance, as the time and track are likely to be predicted with great accuracy. Dr. Brünnow calculates that it will be in perihelion on the evening of August 6, 1855.

The eminent geometer, M. Le Verrier, has shown that there is strong reason to think the comet of De Vico identical with one observed in 1678, by La Hire, and recorded in the *Histoire Celeste* of Lemonnier. The comet of that year was seen near the ecliptic in the constellation Aquarius, and the positions given by the observer do not lay claim to any degree of exactness. M. Le Verrier proves that elements closely resembling those of De Vico's comet will accord sufficiently well with La Hire's observations, and hence the identity of the comets becomes extremely probable. At one time it was thought to be the same comet that appeared in 1585, which was attentively watched by Tycho Brahe, but the computations of MM. Le Verrier and Peters render this very unlikely, notwithstanding a similarity in the elements.

The dimensions of the orbit described by the periodical comet of De Vico in 1844, were as follows:—

	In parts of the earth's mean distance.	In English miles.
Aphelion distance	5·0194	478,300,000
Perihelion distance	1·1890	113,300,000
Minor axis	4·8860	465,600,000

Corresponding period of revolution 5·469 years.

The periodical Comet of Brorsen.

On the 26th of February, 1846, Mr. Brorsen, of Kiel, in Denmark, discovered a telescopic comet in the constellation Pisces, which has been found to revolve round the sun in about $5\frac{1}{2}$ years. It was nearest to the earth on the 27th of March, and at that time appeared as a large roundish nebulosity, without any indications of nucleus or tail. The observations were not very numerous, and, towards the latter part of the series were separated by a long interval, for which reasons the elements of the orbit, and, particularly, the periodic time, could not be exactly ascertained. The epoch of the ensuing arrival at perihelion was, therefore, liable to some uncertainty, and was fixed by one able calculator on September 26th, 1851, and by another about the middle of November. The comet, we believe, was sought for on both suppositions, with more than one of the larger telescopes of the present day, but was not found. It was expected to be fainter than in 1851, and if it arrived at its least distance from the sun in September or earlier, might very easily escape observation. It is to be hoped that observers will be more successful in their search for the comet early in the year 1857.

There seems a probability that the present remarkable form of the orbit is owing to the influence of the planet Jupiter, near which the comet must have passed in May, 1842, as the author has shown by calculation. When it has been again observed, so as to discover the precise length of revolution at the time it was visible in 1846, and thus secure a good starting point, it will be possible to determine very precisely, what effects followed this close appulse, and thus to find the periodic time, and other elements of the comet's orbit, before it passed so near the system of Jupiter. Such inquiries are amongst the most interesting in the whole science of astronomy, though involving a long and laborious application of very abstruse and intricate formulæ.

Dr. Brünnow, who has paid much attention to the movements of this comet, gives strong reasons for disputing its identity with the comets of 1532 and 1661, long supposed to be the same, though the three orbits have a striking resemblance to each other, as the reader may see by comparing the numbers in our general table. We subjoin the dimensions of the orbit of Brorsen's comet.

	In parts of the earth's mean distance.	In English miles.
Aphelion distance	5·6429	537,750,000
Perihelion distance	0·6501	61,950,000
Minor axis	3·8307	365,100,000

The corresponding period is 2039 days, or 5·581 years.

The Periodical Comet of D'Arrest.

On the 27th of June, 1851, Dr. D'Arrest of Leipzic discovered a faint telescopic comet in the constel-

lation Pisces. As early as July 8th it was remarked by this astronomer that the course the comet was pursuing did not appear reconcileable with a parabolic curve, and as observations were multiplied it became evident that the true orbit was elliptic, and that the time of revolution round the sun extended only to a few years. The latest investigation gives a periodic time of 2353 days (6·441 years), the comet having arrived at its least distance from the sun on the morning of July 9th. It was always extremely faint and small, without nucleus or tail, and was not observed more than three months. The elements do not resemble those of any former comet in a sufficient degree to justify the supposition of identity. Dr. D'Arrest has remarked that the comet was for a considerable period in the vicinity of the planet Jupiter in 1849 : it may eventually be found to have undergone large perturbations from the attraction of this great globe, which possibly may have given rise to its present limited path about the sun. The following numbers, exhibiting the dimensions of the orbit of D'Arrest's comet in 1851 must be received with some caution, as the observations have not yet been fully discussed :—

Aphelion distance -	- 5·7497	or	547,900,000	miles.
Perihelion distance -	- 1·1740	or	111,900,000	„
Minor axis of orbit -	- 5·1960	or	495,200,000	„

CHAPTER VIII.

PERIODICAL COMETS (*continued*)—OF SIX COMETS, PROBABLY WITH SHORT PERIODS—LEXELL'S COMET IN 1770—COMETS WHICH APPEAR TO REVOLVE ROUND THE SUN IN ABOUT 75 YEARS—OTHERS TO WHICH LONGER PERIODS HAVE BEEN ASSIGNED.

(1.) *Comets which were probably describing small elliptical orbits at the time they were observed, but whose periods are not yet accurately determined.*

IN this class of comets we shall briefly notice, in chronological order, six of these bodies which should probably be included amongst those of short period, but respecting which our knowledge is not yet sufficiently exact to enable us to predict the time of reappearance. In fact, the first *five* may be considered *lost*, until they are either accidentally rediscovered, or until it has been shown that they have been deflected from their former orbits by the attraction of the larger planets.

I. A comet observed somewhat roughly in February 1743, at Paris, Berlin, Vienna, and Bologna, appears to have been periodic, as the apparent places cannot be represented on the supposition of parabolic motion.

Clausen, founding his calculations on the observations of Zanotti at Bologna, makes the time of revolution 5·436 years. This comet was seen in Ursa Major and Leo.

II. The comet detected by Messier at Paris on the 8th of April, 1766, and afterwards observed by La Nux at the Isle of Bourbon, was undoubtedly moving in an ellipse of moderate length of revolution. Burckhardt made the periodic time a little over five years (5·025 years).

III. A comet discovered by Mr. Pigott, at York, on the 19th of November, 1783, has had elliptical elements assigned to it by the same computers; the period being 5·613 years.

IV. The small comet detected by Pons on the 12th of June, 1819, and roughly observed at Marseilles and Milan, was doubtless one of short period. Professor Encke finds the time of revolution 2052 days, or 5.618 years, but it has not been recognised since 1819. Clausen conjectures that it may be the same as that of 1766, the elements having undergone considerable changes from the attraction of the larger planets, which is by no means an unlikely event.

V. Another small and faint comet discovered in the same year, by Blanpain at Marseilles, on November the 28th, to which Encke assigns a period of 1757 days, or $4\frac{3}{4}$ years, subject, however, to greater uncertainty than in the former case, owing to the greater errors which exist in the observations. The late Professor De Vico, of Rome, computed the amount of perturbation due to the influence of the planet Jupiter up to the year 1836, and found that the comet should

have returned to perihelion towards the end of August in that year, if Encke's numbers were correct. No comet was found, nor has it been recognised since the year 1819. Clausen suggests that this may have been the comet which was observed in February 1743, as noticed above.

VI. The comet found by Dr. Peters, at Naples, in June, 1846, and followed until the end of July, is supposed to be periodical. The time of revolution is 15·89 years, according to D'Arrest, and 12·85 years agreeably to the calculations of the discoverer, who thought his result was uncertain to the extent of one year. In this case, we may expect the re-appearance of the comet between 1858 and 1860, the most probable epoch we can fix upon being the spring of 1859. It was always small and faint, and with the exception of a single observation at Rome, was observed only at Naples. The six comets which we have included in the present class all move in the same direction as the earth. In four cases the inclination of the orbit to the plane of the earth's path is less than *eleven* degrees, the perihelion distance being in each instance within the orbit of our globe. The comets of 1783 and 1846, which have much larger inclinations, have their perihelia nearer to the orbit of the planet Mars.

(2.) *Lexell's Comet of* 1770.

There is one body which we should perhaps have included in the above division, had not the interest attaching to the form of its orbit when last observed, and its extraordinary history, claimed for it something more than a passing mention. We allude to the remarkable comet discovered in June 1770, by Messier

of Paris. When first perceived, it was pretty bright, its nucleus shining like a star, and resembled the nebula between the bow and head of Sagittarius.

On July 1st, it had greatly increased in apparent size, and though no tail was visible, the white nebulosity surrounding the nucleus extended over a space of $2\frac{1}{3}°$, or more than five times the diameter of the moon. At this time the comet was very near the earth, as we shall presently notice more particularly. It continued visible till the beginning of October, when it had become very small and faint. Several astronomers, and amongst them MM. Pingré and Prosperin endeavoured to represent the apparent track of the comet in the heavens by means of parabolic elements, but without success. M. Lexell of the Academy of Sciences at St. Petersburg has the merit of having first pointed out the true form of the orbit described by the comet. He proved that a period of seven years was too long, and finally arrived at the conclusion that the true periodic time, in 1770, was five years and seven months. These results were not obtained until 1778, or two years after the comet should have returned, supposing Lexell to be correct in the length of a revolution. At that time a very close search was kept up by Messier and others for new comets, and it was supposed that the one in question must have escaped observation during its descent towards the sun, in 1776, owing to its proximity to that luminary —a very likely event. During the course of his researches, Lexell remarked that the comet must have made a very close approach to the planet Jupiter, at the end of May, 1767, when the distance between the two

bodies was probably only $\frac{1}{580}$th of the comet's distance from the sun, and hence it appeared the influence of the planet was three times greater than that of the sun:—the motion of the comet at this part of the ellipse being comparatively slow, it was exposed for a considerable period to the disturbing action of Jupiter. These circumstances, Lexell thought, would give rise to most important changes in the form of the comet's path round the sun, so that the small ellipse in which it was moving when visible from the earth in the summer of 1770, might have been the result of Jupiter's powerful attraction.

Another re-appearance of the comet, on the supposition of a periodic revolution of five years and seven months, would fall due about the month of August, 1781, and Lexell, in drawing attention to this fact, gave a series of ephemerides to facilitate the comet's discovery. In the same memoir he pointed out a close appulse between Jupiter and the comet, which would take place after the aphelion passage, or about August 23rd, 1779, when he found the action of the planet would exceed that of the sun 225 times, and hence it was possible the path of the comet might again suffer a total change. Though astronomers searched the heavens diligently about the time of the expected reappearance, the comet was not seen, and, according to the results deduced by Lexell, it was inferred that the comet had again been deflected from its course by the overpowering attraction of the planet Jupiter, and moved after this encounter in a very different, though unknown, orbit. The labours of Lexell in clearing up the history of this body were

so great, that by most authorities it has been called '*Lexell's* comet.'

Nothing further was known respecting it until the year 1806, when Burckhardt, an eminent French calculator, verified Lexell's calculations; and subsequently, at the request of Laplace, investigated the effects of Jupiter's action upon the comet in 1767 and 1779, with the help of formulæ devised by Laplace, and published in the *Mécanique Celeste*. Burckhardt's conclusions were received with great interest by astronomers, and we believe every confidence has been placed in them until the subject of periodical comets was taken up so ably by Le Verrier four or five years since. Of the main facts there can be no doubt: the comet certainly twice encountered the planet, in 1767 and 1779, and on each occasion must have been deflected from its previous course into an orbit widely different, but Le Verrier shows that the elements could not be determined from the observations of 1770 with sufficient accuracy to allow of a rigorous computation of the disturbances due to the influence of Jupiter in 1779, and consequently that the numbers which Burckhardt assigned for the orbit after the great perturbations in that year were not certain, while with respect to the elements calculated by the same mathematician prior to the close appulse of Jupiter and the comet in 1767, it was stated that some errors must have crept into the computations, the numbers in the *Mécanique Celeste* being thereby entirely vitiated. Having said thus much, we will subjoin the principal results of Burckhardt's researches, on account of their historical interest, and

the great notoriety they have obtained, and will then more particularly allude to the investigations of Le Verrier, which furnish us with some very interesting conclusions.

The great perturbations of 1767 took place between the middle of January and May. In the latter month the comet was moving in an ellipse, with a periodic time of 2050 days; but before the 18th of January, according to Burckhardt, its time of revolution was $48\frac{1}{2}$ years; the mean distance from the sun was $13\frac{1}{4}$ times the radius of the earth's orbit; and the comet could never approach that luminary within 480 millions of miles, at which distance there would be no chance of seeing it from our globe. Hence it was inferred that the non-appearance of the comet prior to 1770 was fully accounted for. To ascertain the effect of Jupiter's attraction upon the orbit in 1779, Burckhardt started with numbers corrected for the small deflection caused by the near approach of the earth and comet in 1770, assuming a periodic time of 2043 days, when the large disturbances commenced about the end of June, 1779. Following similar methods to those used in the former case, he concluded that the comet escaped from what was termed the *sphere of activity* of the planet early in October, 1779, and at this epoch it was moving in an ellipse, with a revolution of rather more than 16 years, and a perihelion distance of $3\frac{1}{3}$ times the semi-diameter of the earth's orbit, and at such a distance there would be no hope of our ever seeing it again. We must mention, as one result of Burckhardt's researches, that the earth diminished the time of the comet's

revolution in June and July, 1770, more than two days. Its reaction upon the earth was quite insensible, and Laplace considered its mass must be less than $\frac{1}{5000}$ of that of our planet, or its influence might have been perceptible upon the solar tables.

M. Le Verrier communicated the principal results of his researches on the comet of 1770 to the Paris Academy of Sciences in May 1848. It is found that the observations of Messier in 1770 do not suffice to determine exactly the length of the major axis of the comet's orbit, and consequently of its period of revolution during the time it was visible, whence it is impossible to assign the exact amount of perturbation which the elements would undergo in 1779, since the computed positions of the comet in its orbit at that epoch may not be the true ones, and the effect of Jupiter's attraction will remain uncertain, as the real distances between the two bodies is to a certain degree indeterminate. But M. Le Verrier proceeds to show that the elements as a whole, subsequent to the year 1779, are far from being *arbitrary;* if one of them be assumed, there exist only two systems of values for the other five elements, and hence we have a 'criterion' by which to judge of the possible identity of the comet of 1770 with any other that has appeared since that year. In this way it is found that the comets of Faye, De Vico, and Brorsen (all of short period) are quite distinct from Messier's. In a similar way M. Le Verrier assigns limits between which the elements prior to 1767 must have fallen, and with the help of his formulæ he is able to show that not any of the ancient comets can have been identical with the one

in question. It is remarked that some error exists in Burckhardt's calculation, as the perihelion distance before the commencement of the year 1767 could not have exceeded three times the radius of the earth's orbit, and much more probably was comprised between 1·5 and 2. The inclination of the comet's path to the ecliptic before the great perturbations of 1767 might have amounted to 37°, though less than 2° when Messier observed in 1770. The final conclusion from M. Le Verrier's investigations is that the comet of 1770 may be considered lost until it is accidentally rediscovered in the ordinary course of searching for these bodies, when his formulæ will enable the astronomer to recognise in the new comet that interesting wanderer.

The comet of Lexell has made a nearer approach to the earth than any other on record. Dr. Clausen of Dorpat, has shown that the distance between the centres of the two bodies about five o'clock on the evening of July 1st, was only 363 semi-diameters of our globe, or rather more than 1,400,000 miles. At this time, as we have already remarked, the nebulosity surrounding the nucleus subtended an angle of 2° 23′, whence it would appear that the real diameter of the comet was 59,000 miles.

Before concluding we may state that a part of the calculations of Burckhardt have been very lately performed again by Dr. Brünnow, who considers his results confirmatory of those in the *Mecanique Celeste.*

(3) *On certain comets which appear to revolve round the Sun in about 75 years.*

There are four comets besides that known as Halley's, which have periods a little over 70 years, and consequently, mean distances rather less than the radius of the orbit of Uranus; this singular circumstance, notwithstanding the difficulties which present themselves in the way of such an inference, would almost lead us to conclude that they have had a common origin at some distant epoch, when a great comet had been separated into several parts, either by collision with one of the larger planets or other cause. We are not, however, to be understood as advocating the probability of such an event, though one able writer has endeavoured to show by calculation, the possibility that three out of the four comets may at some past time, have formed a much larger one, which exploded in the neighbourhood of the planet Mars. The comets we are about to notice, all move according to the order of signs, or in the same direction as the earth, with large inclinations to the ecliptic; in these respects they differ from the comet of Halley. We shall take the four in the order of discovery.

I. A comet discovered by Pons in July, 1812, in the constellation Lynx, and, shortly after, visible to the naked eye, with a conspicuous tail.

II. *The comet of Olbers*, detected by that active astronomer on the 6th of March, 1815, and observed till the end of August. The periodic time has been well determined by the late Professor Bessel, who

finds that the comet will again arrive at perihelion in February, 1887. The action of the planets will hasten its return no less than two years.

III. The comet discovered at the Collegio Romano, at Rome, by De Vico, on the 20th of February, 1846, and just visible without the telescope, early in March.

IV. A comet found by Brorsen, in July, 1847, and observed till the middle of September.

We subjoin the numbers required for constructing the orbits of these interesting bodies, merely remarking that the quantities are far more exact in the case of Olbers' comet, than in the others, owing to the researches of Professor Bessel. The distances, &c., are expressed in semi-diameters of the earth's orbit: the periods in years and decimals.

Comet.	Aphelion Distance.	Perihelion Distance.	Minor Axis.	Period of Revolution
Pons, 1812*	33·414	0·777	10·192	70·68 yrs.
Olbers, 1815 . . .	34·055	1·213	12·854	74·05 „
De Vico IV., 1846 .	34·351	0·664	9·550	73·25 „
Brorsen III., 1847. .	35·071	0·488	8·273	74·97 „

The other elements will be found in the general table.

* The author drew attention to this singular group of comets in the *Astronomische Nachrichten* some time since, instancing the comets of Olbers, De Vico, and Brorsen, but, by an over sight, omitting that of Pons, which was soon after added by Professor Stephen Alexander, of New Jersey, U. S. While these sheets are passing through the press, it is announced that the comet discovered in June, 1852, by Dr. Westphal, at Göttingen (the last in our general table), has a periodic time of about sixty-nine years, and may therefore belong to the above group. This body has also *direct* motion and a large inclination.

(4.) *Comets to which Long Periods of Revolution have been assigned.*

In addition to the comets of short period there are many for which ellipses with much longer revolutions have been calculated at various times,—these we shall place in a class by themselves. It is, however, to be understood that in some instances there is a high degree of probability attaching to the periodic times; while in others, the numbers attributed are to be regarded as little better than the mere results of calculation, or as affording no trustworthy idea of the true time of revolution. For the sake of a methodical arrangement, we will take these comets in chronological order, and endeavour at the same time to distinguish between the *probable* and *uncertain* periods.

1680. Professor Encke, from elaborate investigations, found the shortest probable revolution of the great comet of this year, 805 Julian years, while the observations might be pretty well represented by supposing a hyperbolic orbit. This body approached very near the sun, and passed over a great angle of true anomaly before it was visible after perihelion passage; consequently, the heliocentric arc traversed during the observations was very small, and errors of observation, otherwise insignificant, are enormously exaggerated in the final elements. Little dependence, therefore, can be placed upon any results of computation for this comet.*

* See a paper, by the author, on the 'Supposed Period of Revolution of the Great Comet of 1680,' read before the Royal Astronomical Society, in March, 1852, and published in their 'Monthly Notices.'

1683. A revolution extending to 190 years is assigned by Clausen's calculations, upon the data furnished us by Flamsteed, the first astronomer royal at Greenwich. *Very uncertain.*

1763. Burckhardt made the time of revolution of a comet in this year, 7334 years, while Lexell found it 1137 years. The great difference between these numbers is of itself sufficient proof that little or no dependence can be placed upon either.

1769. Some years since the late Professor Bessel, of Königsberg, investigated the elements of the fine comet of 1769: he considered the most probable period 2090 years, but showed that what might be regarded as insignificant errors of observation, would suffice to diminish the time of revolution to 1692, or to increase it to 2673 years. Other calculators have occupied themselves with the discussion of the observations of this comet, but their deductions are superseded by the more probable conclusions of Bessel.

1807. Professor Bessel, in a classical memoir on the subject, makes the duration of a sidereal revolution 1714 years, which may be considered at least an approximation to the truth.

1811. The first or great comet of 1811 is stated by Argelander to have had a period of 3065 years at the time it was observed. On this point the reader is referred to the following chapter.

1811. The second comet of this year, which was discovered by Pons on November 16th, and seen for three months, is computed by Nicolai to have a period of 875 years, and with some degree of probability.

1822. Professor Encke finds a revolution of 5444

years for the fourth comet of 1822, detected by Pons at Marlia on July 13th, and observed subsequently at various places in Europe and also in New South Wales.

1825. The great comet of this year has a revolution of 4386 years, according to Professor Hansen. This result doubtless admits of correction, as there are large outstanding differences between the calculated and observed places of the comet.

1840. The fourth comet discovered by Dr. Bremicker at Berlin, is found by Mr. Götze to have a period of 344 years, which time he considers to be correct within ten years. This conclusion deserves confidence.

1844. On the 7th of July a comet was discovered by M. Mauvais at Paris, which remained visible in powerful telescopes until April of the following year. During this interval it was observed with all the accuracy of which modern instrumental means admit, and the rigorous discussion of the whole series of observations might, therefore, be expected to conduce to some results closely approximating to the truth. After an elaborate and masterly inquiry, Professor Plantamour, of Geneva, finds a periodic time of 102,050 years! subject to an uncertainty of about 3090 years. This, of course, is one of those instances where it is impossible to determine the length of a comet's revolution, owing to the slight deviation of the orbit from a parabola. We may be certain, however, that it extends to many thousands of years.

1845. A comet found by Colla, at Parma, early in June, and visible to the naked eye soon after, is pro-

bably periodical. From a similarity between the elements of this body and those of the comet observed by Tycho Brahe, in 1596, Dr. D'Arrest was led to suspect their identity, and has accordingly tried how a period of 249 years (the interval between 1596 and 1845), would agree with the observations: his inference is, that the agreement is sufficiently close to warrant an opinion that the comets were the same.

1846. De Vico's third comet. Dr. Jelinek, of Prague, assigns a period of 2720 years, which is stated to be uncertain within 400 or 500 years.

1846. Brorsen's second comet. Dr. Wichmann, of Königsberg, was led to infer, from his own observations, that the length of a revolution was about 401 years, while Mr. Oudemanns makes it 500 years. A closer investigation might, perhaps, lead to more exact numbers: the elliptical character of the orbit is certain.

In the next chapter we shall notice more fully several of the comets included in the present section.

CHAPTER IX.

A BRIEF NOTICE OF SOME OF THE MOST REMARKABLE COMETS THAT HAVE BEEN OBSERVED FROM THE EARLIEST TIMES TO THE PRESENT DAY.

ABOUT A.C 134, at the time of the birth of Mithridates the Great, a very splendid comet made its appearance, according to Justin, and remained visible seventy days. Its brilliancy is compared to that of the sun; the tail covered a fourth part of the heavens, and was four hours in rising. There is strong reason for supposing this fine comet the same as the one observed in China, from July to October, A. C. 134, in the northern and eastern heavens, with a train extending past the zenith. Some writers have conjectured that the comet of Justin may have been that now known as Halley's, but there is pretty decisive evidence to the contrary.

A.D. 178. A remarkable comet was observed by the Chinese in the autumn. The nucleus had a reddish tinge, and moved from the constellation Virgo, through Ophiuchus and Serpens into Eridanus in about eighty days. The tail, at one period, was between 50° and 60° in length. Few comets have described a longer track in the heavens, and continued visible to the naked eye during a longer period than that of 178.

389. A comet is mentioned by contemporary historians which almost equalled in brilliancy the planet Venus. They describe the head as composed of several small stars; the tail was sword-shaped, and the whole phenomenon resembled a burning lamp, with the flame extending upwards from the horizon. The sight of this 'prodigy' is said to have inspired the greatest terror.

582. According to the Chronicle of Idatius, a large comet appeared in this year. 'It was surrounded by a thick darkness, and situated in a kind of opening; it shone in the midst of the darkness.' It was accompanied by a tail of surprising magnitude, which resembled the smoke of a distant conflagration, and was observed in the western heavens about the first hour of the night, or soon after sunset.

615. A comet was seen in China in the sixth moon, or about July. It was of a dusky colour, and during the night the upper extremity of the tail had a kind of vibratory motion: the length of the train was between 50° and 60°. This is, perhaps, the first distinct mention of coruscations in the tail of a comet.

891. A great comet was observed both in Europe and China, in May, 891; its path was from Ursa Major, through Bootes into Ophiuchus and Serpens. The Chinese say the tail was 100° long, and it is described by European historians as of astonishing magnitude and brilliancy.

1402. A very splendid comet made its appearance in the spring of this year. Judging from the vague accounts left us by eye-witnesses, we may infer that it was one of the finest comets recorded in history. It

was observed in Italy between the west and north, with a tail directed towards the north-east. It increased daily in size and brightness as it approached the sun. On Palm Sunday, March 19th, and two following days, its increase was 'prodigious.' On Sunday the tail was 'twenty-five fathoms long,' on Monday, fifty, and the same day one hundred; on Tuesday more than two hundred. These numbers enable us to estimate the relative length on different days. After March 21st, the comet was not seen in the evening in Italy, but it was observed near the sun, which it preceded. The brightness was such that the light of the sun did not prevent its being seen at mid-day. It caused great terror amongst the ignorant, who considered it the presage of many evils to men in general. The comet was observed in Japan, but unfortunately we have no account of it in the Chinese Annals. A *second* comet appeared in the same year, about the end of spring, in the western heavens: it was bright and clear, with a tail 'like a long pike,' stretching out towards the east. After sunset its brilliancy is described as most intense. It was seen *day and night*, and moved from the west eastwards. 'This prodigy,' says Ducas, 'was remarked in the Indies, in Chaldea, Phrygia, Persia, Asia Minor, Thrace, in the country of the Huns, Dalmatia, Italy, Spain, Germany, and in all the countries bordering upon the ocean. This wonderful phenomenon continued until the autumnal equinox, and did not disappear till the sun was already advanced in the sign Libra; it was termed *Lampadias*.' Other historians mention the second comet of 1402, which could have been but little inferior to the first in splendour.

1472. The most celebrated comet of the fifteenth century, was that which became visible early in December, 1471, but was especially remarked about the third week in January of the following year. Towards the 20th of this month it increased to an astonishing size, throwing out a tail of prodigious length, and presenting altogether a spectacle, which, in the language of the age, is described as very horrible, and causing universal dread. There was one European observer, however, who viewed it in a different light, and through whose account of its apparent path in the heavens, Dr. Halley was enabled to compute the elements of the real orbit. Regiomontanus discovered it on the 13th of January, amongst the stars of Virgo, under the sign Libra. The motion of the head was very slow at first, but became much more rapid as it passed through Bootes. About January 21st, it traversed an arc of 40° of a great circle, being then about the middle of Cancer. Its after course was between the poles of the equator and ecliptic, through Cepheus, Cassiopea, Andromeda, and Pisces into Cetus, where it disappeared about the end of February. When nearest the earth on the 21st of January, it was visible in full daylight, and its tail stretched across the heavens: it was distant from our globe at this time less than 3,350,000 miles. The Chinese have a long account of the position with respect to the stars on different days. The comet moved very nearly in the same plane as the earth.

1577. The comet of this year deserves mention chiefly on account of its having been the object of Tycho Brahe's investigation on the parallax of these

bodies. On the day of discovery it exhibited a curved tail 22° in length. The Chinese describe it as of a bluish colour, with a white vapour about 10° long. Tycho Brahe concluded there was no sensible parallax, and, therefore, that the comet must have been situated far beyond the moon.

1618. Several comets were observed in this year, but the finest was that discovered by Kepler, Longomontanus, Gassendi, and many other astronomers, about the end of November. The tail was of unusual length, exhibiting coruscations, especially to Longomontanus on December 10th, when it extended over an arc of no less than 104°, '*cum vibratione enormi.*' The comet was observed by our countryman Harriot, whose results have been discussed by Professor Bessel. Cysat remarked a circular nucleus in the centre of the head about 2′ diameter.

1652. Hevelius attentively observed the comet of this year. It was of a pale and livid colour, but almost equalled the moon in size, according to the judgment of Hevelius and Comiers.

In 1661, 1664, and 1665, fine comets were visible. The last two form the subjects of a great folio volume, in the *Theatrum Cometicum* of Stanislaus Lubienietski. Both exhibited tails, but if we may depend on the drawings, the train in the comet of 1664 proceeded directly from the nucleus, without an envelope, while that of 1665 presented an extensive envelope, which, partly encircling the nucleus, formed the origin of a somewhat lengthy tail.

1680. The famous comet which astonished the world at the close of the year 1680, and beginning of

1681, was discovered by Godfrey Kirch, at Coburg, in Saxony, on the 14th of November, in the constellation Leo. It was noticed before the end of the same month at various places in Europe and America. The perihelion passage took place on the 18th of December, and the comet was lost in the sun's rays about ten days previously: nevertheless it had exhibited a very imposing appearance, with a tail varying from 15° to 30° long. After perihelion, however, about the 20th of December, when it became visible in the evening sky, it was the object of universal attention, the train extended over a vast arc of the sky, frequently appearing from 70° to 90° in length, and sensibly curved at the extremity so as to resemble an enormous sabre. The nucleus presented itself under various forms. By some it was described as a confused mass of light not particularly bright to the naked eye. In the telescope it was like a 'burning-coal.' The tail was the most remarkable feature, and its situation in the heavens was such as to render its whole length distinctly visible, especially during the first fortnight in January, 1681. The comet was observed in all parts of the world, and was last seen by Sir Isaac Newton with a seven-feet telescope on the 19th of March. This great mathematician having devised methods of representing the apparent motion of comets by parabolic curves, calculated the elements of the orbit for the one in question, as did also his friend and assistant Dr. Halley. The results showed that the comet at its perihelion passage, almost grazed the sun's surface, so close did it approach to that luminary, and this remarkable circumstance

gave rise to much speculation as to the probable consequences of such proximity to the great origin of heat and light. Dr. Halley, on searching the catalogues of ancient comets, considered he had found three which gave signs of identity with that of 1680, viz., those of 1106, 531 and B.C. 43, and his inferred time of revolution 575 years has long been accounted the true period of that comet. Since his time, however, much more information relative to these ancient comets has been discovered in the various European chronicles, and in the annals of China; the tendency of this additional evidence is adverse to Halley's conclusion, but it would lead us far beyond our limits to discuss the question at length. In 1818, Professor Encke collected together all the observations he could find on the comet of 1680, and after a most complete investigation, he ascertained that the probable period of revolution resulting from the observations, is no less than 8800 years, but the uncertainty of the data is such that they may be satisfied within their probable limits of error, by an ellipse with a periodic time of 805 years, or, by an hyperbolic orbit. Flamsteed's and Newton's observations alone give a period of 3164 years. It is clear, therefore, that no definite knowledge of the length of the comet's excursion into space can be obtained from the observations, and notwithstanding Whiston's fanciful theory of the comet's past movements, based upon a presumed revolution of 575 years, and the conjectured identity of this body, with the prodigy which appeared at the time of the destruction of Troy, or the brilliant star

during the reign of Ogyges, the testimony of history is against the supposed revolution of Halley.

1744. The most splendid comet of the eighteenth century, appeared in this year. It arrived at perihelion at the beginning of March, and during the previous month formed a very conspicuous object in the western sky. On the 7th of February the tail was 20° long; the head seemed pretty round on this day, but on the 11th it was oblong in the direction of the tail, and was divided by a black line into two parts, the northern one much smaller than the other, with a coma brighter than the tail. This singular figure disappeared on the following days. On February 15th, the tail was divided into two branches; the eastern portion 7° or 8° long, the western 24°. On the 23rd it became curved, the convexity on the west side. On the 7th of the same month, the light of the comet equalled that of Jupiter at his greatest brilliancy, and on the 11th was little inferior to Venus. On the day of perihelion passage, the head was prodigiously bright, it was seen with the telescope in broad daylight, and many persons followed it with the naked eye, some time after the sun had risen. This splendid object was observed by nearly all the astronomers of the time, and gave occasion for many dissertations on comets. Cheseaux affirms that six tails were visible at one period, but the most eminent observers in England and France have no mention of such an extraordinary phenomenon.

1769. Another remarkable comet appeared in the autumn of this year, and was watched by our astro-

nomer royal Dr. Maskelyne, and by M. Messier, at Paris. About the middle of September, the tail attained a length of between 90° and 100°, exhibiting undulations of light, and a curvature towards the extremity. The extent of the train varied considerably according to different observers, but the discordances between their estimated lengths are evidently owing to atmospherical circumstances. Professor Bessel has fully investigated the elements of the comet of 1769.

1807. The comet of this year was distinctly visible to the naked eye, and was examined with the powerful reflectors of Sir William Herschel. It had a well defined planetary disk of a circular form, the diameter of which was determined by Sir William to be about 538 miles. The real length of the tail on October 18th, was nine millions of miles, though owing to the effect of foreshortening it did not appear above 3½° long. The researches of Professor Bessel assign a periodic revolution of 1714 years, but it may possibly be as long as 2157 years, or may not extend over more than 1404 years.

1811. The first or great comet of 1811 is perhaps the most famous of modern times. Independently of its great magnitude, the position of the orbit and epoch of perihelion passage were such as to render it a very splendid circumpolar object for some months. It was detected with the aid of the telescope by M. Flaugergues, at Viviers, on the 26th of March, 1811, and was last seen by Wisniewski, at Neu-Tscherkask in the south of Russia, on the 17th of August, 1812. In the autumnal months of 1811, the bright nucleus and tail became visible soon after

the shades of evening closed in, and continued so throughout the night, the high northern declination causing the comet to appear constantly above the horizon in these latitudes. The tail was longest about the end of the first week in October; it then extended over an arc of 25°, and was 6° broad. According to the observations of M. Bouvard, the tail was divided into two branches after the end of August, making an angle of little less than 90° with each other. Sir W. Herschel paid close attention to this comet: he distinctly saw a well-defined planetary disk involved in the nebulosity forming the head, and by accurate measurement determined its real diameter to be about 430 miles. This disk was of a pale ruddy colour; the surrounding nebulosity greenish or bluish green. When the comet was examined with high magnifiers, the appearance of a stellar nucleus vanished, and the light was spread, though not uniformly. The real length of the train about the middle of October was upwards of one hundred millions of miles, and its breadth about fifteen millions. According to the calculations of Professor Argelander, the most complete that have been made, the period of revolution at the epoch of perihelion in 1811, was 3065 years, subject to no greater probable error than 43 years.* But on computing the variation of the greater axis due to the attractions of the larger planets up to May, 1827, he ascertained that the revolution would be shortened even in this brief interval by no less than 177 years, or that the periodic

* The following numbers, which deserve confidence, represent the dimensions of the orbit of the comet of 1811 *in that*

time corresponding to the end of May 1827, was about 2888 years. How much further it may be altered, will probably be left for determination by those who may be interested in its return. Another comet was observed in 1811, but it was very far inferior to the first in splendour.

1819. In July of this year, a fine comet suddenly became visible in the constellation Leo. M. Cacciatore, of Palermo, assures us it exhibited phases similar to a crescent moon, during part of its visibility, and that the crescent was not always on the same side of the nucleus. This remark proves that the phase could not have been owing to reflected light from the sun, such as produces the varied phases of Mercury and Venus, and M. Arago has drawn particular attention to this fact. The tail extended about 7° from the nucleus. The observed path of this comet is very well represented by a parabolic curve, so that the period of revolution, if the real orbit be elliptical, must extend to many centuries, and perhaps to some thousands of years.

1825. In July, 1825, a comet was discovered independently by M. Pons, at Marseilles, and M. Biela, at Josephstadt, which continued visible until the

year, and afford a striking idea of the enormous distances to which some of these bodies travel.

Aphelion distance -	421·015 or	40,121,000,000	miles.
Perihelion distance -	1·035 or	98,700,000	miles.
Minor axis - - -	41·76		

This comet therefore recedes from the sun to a distance of *fourteen* times that of the planet Neptune.

middle of July, 1826. It was most conspicuous at the beginning of October, when the head was approaching our southern horizon. The tail appeared about 15° long, and was divided into two branches. On the 6th of this month, Professor Santini saw the nucleus composed of three bright points. The period of revolution of this fine comet, is probably not less than 4000 years. It is known as the 'great comet of 1825,' several others having appeared in the same year.

1843. The finest comet of the present century was that which made its appearance at the end of February, 1843. On the 28th of that month it was observed in full daylight near the sun, at Guadaloupe y Calvo, in Mexico; at Portland, in the United States of America; on board the East India Company's ship, Owen Glendower, off the Cape of Good Hope; and at Parma, Bologna, Genoa, and other places in Italy. It presented a most splendid appearance during the first week in March throughout the southern hemisphere, but when it became suddenly visible above the horizon in these latitudes, about the 17th of that month, its brilliancy had very much diminished: nevertheless the tail still covered an arc of the heavens of no less than 40°, and was curved towards the extremity. Undulations similar to those recorded in the trains of some of the great comets of past times were generally remarked. The suddenness of its apparition in this country added not a little to the interest which such an object was certain to excite. No accounts from more southern latitudes reached us for some days, and even astronomers were somewhat puzzled as to the nature of the

strange ray of light which, rising above the clouds or haze of the western horizon, soon after sunset, stretched over the south-west sky towards the constellation Lepus through more than 35°. The nucleus of this comet is described as small, but extremely bright, of a golden hue, of the colour of Venus, or reddish, according to different observers. On the 11th of March it exhibited a well-defined planetary disk, which, by accurate measurement, must have exceeded 4500 miles in diameter. The average length of the tail in March was about 35°, but on the evening of the 3rd a faint ray extended as far as 65° from the nucleus. At this time the train is described by an observer at Brazil as of a brilliant silver colour, but with a streak of a bright golden hue running directly into it from the head to an extent of four or five degrees. Early in the month it was divided into two branches, which subsequently united into one long narrow stream of light.

The orbit of this comet approaches closer to the sun than that of any other hitherto observed, not excepting the famous comet of 1680. According to the most trustworthy calculations, the perihelion distance was only 538,500 miles; therefore the centre of the comet would be distant from the *surface* of the sun's globe less than 96,000 miles!

Several comets have been mentioned as probably identical with the great one of 1843, and in particular those of 1668 and 1689, which exhibited tails of unusual length. If it were one and the same comet that appeared in 1668, 1689, and 1843, the period of revolution could differ but little from twenty-two

years. But, independently of the *primâ facie* improbability of this short period, the evidence afforded by the history of comets in past ages is decidedly against it. Neither is the period of thirty-five years, suggested by some astronomers, more probable, for the comet of 1106 which was cited as strongly supporting this time of revolution, could not possibly have been the same as the comet of 1843, since historians agree in stating that it was observed for some time in the northern heavens, a circumstance perfectly irreconcilable with the elements of the latter body, which can only remain *about three hours* north of the ecliptic. Calculation shows that the paths of the comets of 1668 and 1689 might be tolerably well represented by the orbit of the comet of 1843, but equally well, in the former case, and much nearer in the latter, by numbers altogether different, so that we can come to no definite conclusion on the subject.

CHAPTER X.

ON THE EXPECTED GREAT COMET.

ONE of the grandest comets mentioned in history is that which made its appearance in the middle of the year 1264. It is recorded in terms of wonder and astonishment by nearly all the historians of the age: no one then living had seen any to be compared to it. It was at the height of its splendour in the month of August, and during the early part of September. When the head was just visible above the eastern horizon in the early morning sky, the tail stretched out past the mid-heaven towards the west, or was fully 100° in length. Both Chinese and European writers testify to its enormous magnitude. In China the tail was not only 100° long, but appeared curved in the form of a sabre. Its movement was from Leo, through Cancer and Gemini, into Orion. It continued visible until the beginning of October, historians generally agreeing in dating its last appearance on the 2nd of October, or 'on the night of the death of Pope Urban IV, of which event it seems to have been considered the precursor. It would lead us beyond the limits of the present work, were we to attempt to discuss the

rude accounts which have descended to us; we must, therefore, content ourselves with stating that some rough approximations to the elements have been attempted in the first instance by Mr. Dunthorne, in the middle of the last century, and subsequently by M. Pingré, the well-known French writer upon the history of comets.

In 1556, at the latter end of February, or early in March, a comet became visible in the zodiacal constellation Virgo. It was closely watched at Vienna, by Paul Fabricius, astronomer at the court of the Emperor Charles V., and we have a rudely executed map of its path amongst the stars in the Book of Prodigies, Omens, &c., published by Lycosthenes or Conrad Wolfhardt, at Nuremburg, in the year of the comet's appearance. It was not nearly so conspicuous as that of 1264, but still is described as a 'great and brilliant star.' Its course lay through Virgo and Bootes, past the pole of the heavens, into Cepheus and Cassiopea, where it was last seen about the end of the third week in April, according to European authorities, though the Chinese observers, who paid great attention to comets, did not lose sight of it till the 'second day of the fourth moon' corresponding to May 10th old style: they discovered it on the 1st of March, a little below the equator, amongst the stars of Virgo.

Our countryman Dr. Halley, the second astronomer royal, calculated the elements of the comet of 1556, from the observations of Fabricius, and gave them, with many others, in his synopsis of *Cometary Astronomy*, which was published early in the eighteenth century.

Owing to the imperfect nature of these observations,

his elements were not considered so exact as those of other comets he had calculated, since it appeared difficult to reconcile the whole series with any rigorous computation. Mr. Dunthorne, some fifty years later, was induced to try the determination of an orbit for the comet of 1264, having at his command two definite observations of position, purporting to have been made at Cambridge by Friar Giles, besides the rude descriptions to be met with in English and Foreign chronicles of that age. His results were so similar to those Halley had given for the comet of 1556, that he was immediately led to conclude the bodies of these years were identical, and the period being probably about 292 years, he surmised that a reappearance might be expected about 1848. Mr. Dunthorne's memoir on this subject was read before the Royal Society of London, and is published in their transactions.

About twenty years later, M. Pingré very materially strengthened the evidence in favour of this conclusion. He collected together at a great expense of time and trouble all the accounts he could find in the chronicles and histories of the thirteenth century relative to the comet of 1264, and was successful in finding many that were unknown to Mr. Dunthorne, and contained valuable information on the subject of his inquiry. The result of an elaborate memoir communicated to the Paris Academy of Sciences in 1760 is, that the paths of the comets of 1264 and 1556 may be represented with tolerable accuracy, considering the nature of the observations, by elements very closely similar; and hence he regarded those

bodies as identical, and coincided with Mr. Dunthorne in anticipating its reappearance about the year 1848. This interesting and valuable paper of M. Pingré's is to be found in the memoirs of the Paris Academy for 1760.

Between the years 1843 and 1847, the author of these pages investigated the question of identity anew, taking as his groundwork, the chart of the path of the comet of 1556, in the work of Lycosthenes already mentioned. After correcting one or two pretty manifest errors, which are not noticed by Pingré, the following orbit was finally fixed upon as the best the observations would afford.

Passage through perihelion in 1556, on April 22nd, at 0h. 34m. p.m. mean time at Greenwich, according to the Julian style of reckoning :—

Place of the perihelion upon the orbit	274°.15′
Longitude of the ascending node	175°.26′
Inclination of the orbit to the ecliptic	30°.12′

Distance from the sun in perihelion, 0·505, or about 48 millions of miles.

The apparent path of the comet amongst the fixed stars deduced from the above elements, agreed so well with that actually observed by Paul Fabricius, that no doubt could remain as to their being a fair approximation to the truth. It became then a matter of great interest to ascertain how these elements would represent the particulars recorded of the comet of 1264. Supposing no great perturbations to have taken place in the interval, the agreement between calculation and observation should be pretty close.

The only point upon which any difficulty could remain, was the time of perihelion passage in 1264, and this was satisfactorily settled by a European observation, cited by Thierri of Vaucouleurs in a poem upon the life of Pope Urban IV., and a Chinese observation some three weeks later, which were found to be strikingly confirmatory of each other.

Supposing the other elements the same as in 1556, allowing only for the precession of the equinoxes in the interval of 292 years, it was found that the path which the comet should have followed in the heavens, was very like that which historians and chronologists ascribe to the grand comet of 1264. This body would become visible about the middle of July, gradually assuming a more imposing appearance towards the middle of August, after which it would recede from the earth and sun, and therefore become fainter, as we are assured was the case. It would traverse Leo, Cancer, Gemini, Orion, and Eridanus, and might finally vanish in the latter constellation at the beginning of October. Hence the author concluded that the comets of 1264 and 1556 were very probably the same, and a return to perihelion might be expected about the middle of the nineteenth century.

We have now to mention a most important investigation relative to the comets in question, by M. Bomme, of Middelburg, in the Netherlands, which has but very recently come into the hands of astronomers. At a vast expense of time and labour, M. Bomme has calculated the effects that will be produced on the period of the comet's return (supposing the identity established) by the united attraction of

the planets Jupiter, Saturn, Uranus and Neptune, and partially of the Earth, Venus, and Mars. In a work of this nature, we can give no idea of the methods upon which the computations have been conducted, and shall therefore merely state the principal results, premising that M. Bomme first assumed the elements given by Halley for 1556, and subsequently those of the author, which were unknown to him at the commencement of his researches. M. Bomme appears to give a preference to the latter, but on this point some caution should be observed.

With Dr. Halley's elements, it was found that at the time the comet was visible in 1264, it was moving in an ellipse with a periodic time of 112,469 days, or 308 years, but perturbations owing to planetary attraction quickened the return of the comet by no less than 5903 days, so that it was in perihelion in April, 1556, and at that time the revolution corresponding to the elliptical arc described, was 112,943 days. Starting again from this epoch, M. Bomme ascertained that the next revolution should occupy 111,146 days, bringing the comet to its perihelion on the 22nd of August, 1860, at which time the revolution will be 113,556 days.

With the author's calculations, on which, as above stated, M. Bomme seems disposed to rely, as being the best of several sets of elements, it was found that in 1264, the ellipse described by the comet had a period of 110,644 days, or 302·922 years, and that planetary disturbances expedited its return by 4077 days. At the time it was visible in 1556, its mean motion corresponded to a period of 308·169 years.

The present revolution should be shortened by perturbations 3828 days, or 10·48 years, and the comet should again reach its perihelion on the 2nd of August, 1858, the revolution belonging to the major axis at that epoch, being 308·784 years.

Hence it appears that there is an uncertainty of two years (between August, 1860, and August, 1858) in the time of the next arrival in these parts of space, according as the elements of Dr. Halley or those of the author are employed, and we may here remark that the computations upon the observations of Fabricius, seemed to establish the position of the longer axis of the ellipse, a most important point, within 4°, which may be regarded as the extreme amount of probable error. This is about the difference between the longitudes of perihelion in the two orbits, and it may therefore be inferred that the 2nd of August, 1858, will probably be within two years of the time of the next perihelion passage: nearer than this it does not appear possible to approximate in the present state of our knowledge. The deviation of 4° in the position of the longer axis of the orbit, causes large differences in the comet's distances from the disturbing planets, and consequently in the estimation of their attractive force at the various epochs, which accounts for the great discordances in the final results.

Such, then, is the present state of this interesting problem, and we have now to look forward to the period 1856—1860 for a confirmation, or otherwise, of the opinions of those astronomers who have occupied themselves with these investigations. M. Bomme's elaborate researches have fully accounted for the non-

arrival of this grand comet at the time originally fixed upon by Dunthorne, Pingré, and others.

It is an important circumstance, as bearing on the question of identity of the comets of 1264 and 1556, that about 289 years anterior to the former epoch, or A.D. 975, a comet of great apparent magnitude was visible, which may very possibly have been the same. It was observed in Europe from August to October, during the reign of John Zimisces. The Chinese saw it about the middle of July, and traced its course through Hydra, Leo, Cancer, Gemini, and Taurus, into Aries, where it was lost after a visibility of three days. It exhibited a tail 40° in length, and was evidently a comet of unusual brilliancy. Supposing the elements fixed by the author for 1556, it is found that the observed track may be very closely represented, the perihelion passage being assumed to take place early in August, 975. A comet observed in China in the summer of 683, and one seen in the circumpolar heavens, A.D. 104, present some indications of identity with the grand comet of 1264 and 1556, but the accounts we possess are too vague to admit of anything more than conjecture.

A CATALOGUE

OF THE

ORBITS OF ALL THE COMETS

HITHERTO COMPUTED,

B.C. 370 TO A.D. 1852.

A Catalogue of the Elements of all the Comets hitherto computed.

Year of Appearance.	Greenwich Mean Time of Perihelion Passage. D. H. M.	Longitude of Perihelion.	Ascending Node.	Inclination.	Perihelion Distance.	Excentricity.	Motion.	Calculator.
B.C. 370	Winter.	150°—210°	270°—330°	Above 30°	Very small		R	Pingré.
136	April 29.	230°	220°	20°	1.01		R	Peirce.
68	July.	300°—330°	150°—180°	70°	0.80		D	Peirce.
11	Oct. 8, 19 12	280°	28°	10° ±	0.58		R	Hind.
A.D. 66	Jan. 14, 4 48	325° 0′ 0″	32° 40′ 0″	40° 30′ 0″	0.445		R	Hind.
141	March 29, 2 24	251 55 0	12 50 0	17 0 0	0.720		R	Hind.
240	Nov. 9, 23 51	271 0 0	189 0 0	44 0 0	0.372		D	Burckhardt.
539	Oct. 20, 14 51	313 30 0	58 or 238	10 0 0	0.341		D	Burckhardt.
565	July 8, 23 51	88 0 0	158 0 0	62 0 0	0.719		R	Burckhardt.
—	July 14, 11 51	80 0 0	159 30 0	59 0 0	0.832		R	Burckhardt.
568	Aug. 28, 6 29	316 47 0	294 36 0	4 2 0	0.889		D	Hind.
—	Aug. 29, 7 46	318 35 0	294 15 0	4 8 0	0.907		D	Laugier.
574	April 7, 6 43	143 39 0	128 17 0	46 31 0	0.963		D	Hind.
770	June 6, 15 22	2 8 0	88 54 0	59 31 0	0.603		R	Hind.
—	June 6, 14 6	357 7 0	90 59 0	61 49 0	0.642		R	Laugier.
837	Feb. 28, 23 51	289 3 0	206 33 0	10 or 12	0.580		R	Pingré.
961	Dec. 30, 3 50	268 3 0	350 35 0	79 33 0	0.552		R	Hind.
989	Sept. 11, 23 51	264 0 0	84 0 0	17 0 0	0.568		R	Burckhardt.
1066	April 1, 0 0	264 55 0	25 50 0	17 0 0	0.720		R	Hind.
1092	Feb. 15, 0 0	156 20 0	125 40 0	28 55 0	0.928		D	Hind.
1097	Sept. 21, 21 27	332 30 0	207 30 0	73 30 0	0.738		D	Burckhardt.

1231	Jan.	30,	7	13	134	48	0	13	30	0	6	5	0	0.948		D	Pingré.
1264	July	15,	23	51	272	30	0	175	30	0	30	25	0	0.430		D	Pingré.
—	July	6,	7	51	291	0	0	169	0	0	36	30	0	0.445		D	Dunthorne.
1299	March	31,	7	29	3	20	0	107	8	0	68	57	0	0.318		R	Pingré.
1301	Oct.	23,	23	51	312	0	0	138	0	0	13	0	0	0.640		R	Laugier.
1337	June	2,	6	26	37	59	0	84	21	0	32	11	0	0.407		R	Halley.
—	June	1,	0	31	20	0	0	66	22	0	32	11	0	0.645		R	Pingré.
—	June	22,	19	12	350	22	0	99	6	0	42	54	0	0.937		R	Hind.
—	June	15,	1	46	2	20	0	93	1	0	40	28	0	0.828		R	Laugier.
1351	Nov.	25,	23	51	69	0	0	....			....			1.0		D	Burckhardt.
1362	March	11,	4	51	219	0	0	249	0	0	21	0	0	0.456		R	Burckhardt.
—	March	2,	7	51	227	0	0	237	0	0	32	0	0	0.470		R	Burckhardt.
1366	Oct.	13,			66	0	0	212	0	0	6	0	0	0.958		...	Peirce.
1385	Oct.	16,	6	14	101	47	0	268	31	0	52	15	0	0.774		R	Hind.
1433	Nov.	5,	4	34	262	1	0	110	9	0	77	14	0	0.329		R	Hind.
—	Nov.	4,	10	10	281	2	0	133	49	0	79	1	0	0.339		R	Laugier.
1456	June	8,	22	1	301	0	0	48	30	0	17	56	0	0.586		R	Pingré.
1457	Sept.	3,	16	48	92	48	0	256	6	0	20	20	0	2.103		D	Hind.
1468	Oct.	7,	9	50	356	3	0	61	15	0	44	19	0	0.853		R	Laugier.
—	Oct.	7,	10	14	1	22	0	71	5	0	38	1	0	0.829		R	Valz.
1472	Feb.	28,	22	24	45	34	0	281	46	0	5	20	0	0.543		R	Halley.
—	Feb.	28,	5	13	48	3	0	207	32	0	1	55	0	0.539		R	Laugier.
1490	Dec.	24,	11	17	58	40	0	288	45	0	51	37	0	0.738		D	Hind.
1506	Sept.	3,	15	53	250	37	0	132	50	0	45	1	0	0.386		R	Laugier.
1531	Aug.	24,	21	19	301	39	0	49	25	0	17	56	0	0.5670		R	Halley.
1532	Oct.	19,	22	13	111	7	0	80	27	0	32	36	0	0.5091		D	Halley.
—	Oct.	19,	14	53	135	44	0	119	8	0	42	27	0	0.6125		D	Mechain.

Year of Appearance.	Greenwich Mean Time of Perihelion Passage. (New Style after 1582.)	Longitude of Perihelion.	Ascending Node.	Inclination.	Perihelion Distance.	Excentricity.	Motion.	Calculator.
A.D.	D. H. M.	° ′ ″	° ′ ″	° ′ ″				
1532	Oct. 18, 7 59	111 48 0	87 23 0	32 36 0	0.5192		D	Olbers.
1533	June 16, 19 31	104 12 0	125 44 0	35 49 0	0.2028		R	Douwes.
—	June 14, 21 11	217 40 0	299 19 0	28 14 0	0.3269		D	Olbers.
1556	April 21, 20 4	278 50 0	175 42 0	32 6 30	0.4639		D	Halley.
—	April 22, 0 34	274 14 54	175 25 48	30 12 12	0.50493		D	Hind.
1558	Aug. 10, 12 25	329 49 0	332 36 0	73 29 0	0.5773		R	Olbers.
1577	Oct. 26, 22 45	129 42 0	25 20 24	75 9 42	0.1775		R	Woldstedt.
1580	Nov. 28, 13 45	109 12 0	19 8 0	64 52 0	0.5955		D	Pingré.
1582	May 6, 16 0	245 23 0	231 7 0	61 28 0	0.22570		R	Pingré.
—	May 7, 8 21	281 27 0	214 43 0	59 29 0	0.04006		R	Pingré.
1585	Oct. 8, 2 45	9 15 29	37 43 52	6 5 4	1.09541		D	Le Verrier.
—	Oct. 8, 0 38	9 8 26	37 44 15	6 5 52	1.09485		D	Peters.
1590	Feb. 8, 3 46	216 54 30	165 30 40	29 40 40	0.57661		R	Halley.
—	Feb. 8, 0 39	217 57 12	165 36 56	29 29 44	0.56772		R	Hind.
1593	July 18, 13 39	176 19 0	164 15 0	87 58 0	0.08911		D	La Caille.
1596	July 23, 14 41	274 24 0	335 39 0	52 48 0	0.5657		R	Valz.
—	July 25, 5 9	270 54 35	330 20 49	51 58 10	0.56715		R	Hind.
1607	Oct. 26, 17 9	301 38 10	48 40 28	17 12 17	0.58798		R	Bessel.
—	Oct. 27, 0 12	300 46 59	48 14 9	17 6 17	0.58418	0.9670888	R	Lehmann.
1618 I.	Aug. 17, 3 3	318 20 0	293 25 0	21 28 0	0.51298		D	Pingré.
— II.	Nov. 8, 8 25	3 5 21	75 44 10	37 11 31	0.38955		D	Bessel.
1652	Nov. 12, 15 41	28 18 40	88 10 0	79 28 0	0.84750		D	Halley.

1661	Jan. 26, 21 9	115 16 8	81 54 0	33 0 55	0.44272		D	Mechain.
1664	Dec. 4, 11 53	130 41 25	81 14 0	21 18 30	1.0258		R	Halley.
1665	April 24, 5 16	71 54 30	228 2 0	76 5 0	0.10649		R	Halley.
1668	Feb. 24, 18 46	40 9 0	193 26 0	27 7	0.2511		D	Henderson.
—	Feb. 28, 19 12	277 2 0	357 17 0	35 58	0.00479		R	Henderson.
1672	March 1, 8 38	46 59 30	297 30 30	83 22 10	0.69740		D	Halley.
1677	May 6, 0 38	137 37 5	236 49 10	79 3 15	0.28059		R	Halley.
1678	Aug. 26, 14 4	327 46 0	161 40 0	3 4 20	1.2380		D	Douwes.
—	Aug. 18, 7 34	322 47 37	163 20 0	2 52 0	1.14530	0.626970	D	Le Verrier.
1680	Dec. 17, 23 51	262 49 19	272 9 33	60 38 37	0.00623		D	Encke.
—	Dec. 19, 23 46	262 49 5	272 9 29	60 40 16	0.00622	0.99998542	D	Encke.
1682	Sept. 14, 19 5	301 55 37	51 11 18	17 44 45	0.58290	0.96792019	R	Rosenberger.
1683	July 12, 17 25	86 31 15	173 17 48	83 47 46	0.55337	0.9832470	R	Clausen.
1684	June 8, 10 17	238 52 0	268 15 0	65 48 40	0.96015		D	Halley.
1686	Sept. 16, 14 34	77 0 30	350 34 40	31 21 40	0.32500		D	Halley.
1689	Dec. 1, 14 56	263 44 45	323 45 20	69 17 0	0.01689		R	Pingré.
—	Nov. 29, 4 48	269 41 6	90 25 24	59 4 30	0.01893		R	Vogel.
1695	Nov. 9, 16 51	60 0 0	216 0 0	22 0	0.84350		D	Burckhardt.
1698	Oct. 18, 16 58	270 51 15	267 44 15	11 46 0	0.69129		R	Halley.
1699	Jan. 13, 8 23	212 31 6	321 45 35	69 20 0	0.74400		R	La Caille.
1701	Oct. 17, 9 51	133 41 0	298 41 0	41 39 0	0.59262		R	Burckhardt.
1702	March 13, 14 33	138 46 34	188 59 10	4 24 44	0.64683		D	Burckhardt.
1706	Jan. 30, 4 23	72 29 10	13 11 40	55 14 10	0.42581		D	La Caille.
1707	Dec. 11, 23 30	79 54 56	52 46 35	88 36 0	0.85974		D	La Caille.
1718	Jan. 14, 21 44	121 39 55	127 55 29	31 8 6	1.02543		R	Argelander.
1723	Sept. 27, 15 4	42 52 35	14 14 17	50 0 18	0.99879		R	Spörer.
1729	June 13, 6 19	320 31 22	310 38 0	77 5 18	4.04350	1.0050334	D	Burckhardt.

Year of Appearance.	Greenwich Mean Time of Perihelion Passage.	Longitude of Perihelion.	Ascending Node.	Inclination.	Perihelion Distance.	Excentricity.	Motion.	Calculator.
A.D.	D. H. M.	° ′ ″	° ′ ″	° ′ ″				
1729	June 12, 17 51	320 27 36	310 38 0	77 5 18	4.04310		D	Burckhardt.
1737 I.	Jan. 30, 8 21	325 55 0	226 22 0	18 20 45	0.22282		D	Bradley.
— II.	June 8, 7 39	262 36 39	123 53 43	39 14 5	0.86700		D	Daussy.
1739	June 17, 10 0	102 38 40	207 25 14	55 42 44	0.67358		R	La Caille.
1742	Feb. 8, 4 39	217 35 13	185 38 29	66 59 14	0.76568		R	La Caille.
1743 I.	Jan. 10, 20 20	92 57 51	67 31 57	2 16 16	0.83818		D	Olbers.
—	Jan. 8, 4 39	93 19 35	86 54 29	1 53 43	0.86155	0.7213085	D	Clausen.
— II.	Sept. 20, 21 17	246 33 52	5 16 25	45 48 21	0.52157		R	Klinkenberg.
1744	March 1, 8 17	197 12 55	45 45 20	47 8 36	0.22206		D	Betts.
1746	Feb. 15, 0 0	140 0 0	335 0 0	6 0 0	0.95		D	Hind.
1747	March 3, 7 11	277 2 0	147 18 50	79 6 20	2.19851		R	La Caille.
1748 I.	April 28, 18 44	215 23 29	232 51 50	85 28 23	0.84040		R	Le Monnier.
— II.	June 18, 21 18	278 47 10	33 8 29	67 3 28	0.62536		D	Bessel.
1757	Oct. 21, 7 55	122 58 0	214 12 50	12 50 20	0.33754		D	Bradley.
1758	June 11, 3 18	267 38 0	230 50 0	68 19 0	0.21535		D	Pingré.
1759 I.	March 12, 13 15	303 10 28	53 50 27	17 36 52	0.58452	0.96768436	R	Rosenberger.
—	March 12, 13 33	303 10 23	53 47 45	17 37 53	0.58452	0.96769237	R	Lehmann.
— II.	Nov. 27, 2 19	53 24 20	139 39 24	78 59 22	0.79851		D	La Caille.
— III.	Dec. 16, 21 4	138 24 35	79 50 45	4 51 32	0.96599		R	La Caille.
1762	May 28, 8 2	104 2 0	348 33 5	85 38 13	1.00905		D	Burckhardt.
1763	Nov. 1, 20 40	84 58 58	356 24 4	72 31 52	0.49829	0.99868	D	Burckhardt.
—	Nov. 1, 20 55	84 57 27	356 17 38	72 34 10	0.49831	0.9954268	D	Lexell.

1764	Feb. 12, 13 42	15 14 52	120 4 33	52 53 31	0.55521		R	Pingré.
1766 I.	Feb. 17, 8 41	143 15 25	244 10 50	40 50 20	0.50532		R	Pingré.
— II.	April 26, 23 44	251 13 0	74 11 0	8 1 45	0.39898	0.864000	D	Burckhardt.
1769	Oct. 7, 14 53	144 11 29	175 3 59	40 45 50	0.12275	0.99924901	D	Bessel.
1770 I.	Aug. 13, 12 28	356 15 11	131 54 54	1 34 31	0.67436	0.7854736	D	Burckhardt.
	Aug. 13, 12 58	356 17 12	131 59 17	1 34 28	0.67445	0.7861193	D	Clausen.
	Aug. 14, 0 39	356 16 27	131 59 34	1 34 31	0.67431	0.786839	D	Le Verrier.
— II.	Nov. 22, 5 39	208 22 44	108 42 10	31 25 55	0.52824		R	Pingré.
1771	April 19, 5 1	104 2 54	27 50 27	11 16 0	0.90337	1.00944	D	Burckhardt.
—	April 19, 5 6	104 3 16	27 51 55	11 15 19	0.90346	1.0093698	D	Encke.
1772	Feb. 19, 2 10	110 14 54	254 0 1	18 17 38	1.01360	0.903148	D	Bessel.
—	Feb. 8, 0 51	97 21 0	263 24 0	17 39 0	0.91180	0.67692	D	Gauss.
1773	Sept. 5, 14 34	75 10 58	121 5 30	61 14 17	1.12689		D	Burckhardt.
1774	Aug. 15, 19 55	317 27 40	180 44 34	83 20 26	1.43287	1.0282955	D	Burckhardt.
1779	Jan. 4, 2 4	87 14 27	25 4 10	32 30 57	0.71316		D	Zach.
1780 I.	Sept. 30, 22 14	246 35 59	123 41 18	54 23 12	0.09630	0.9999460	R	Clüver.
— II.	Nov. 28, 20 21	246 52 0	141 1 0	72 3 30	0.51528		R	Olbers.
1781 I.	July 7, 4 32	239 11 25	83 0 38	81 43 26	0.77584		D	Mechain.
— II.	Nov. 29, 12 32	16 3 28	77 22 52	27 13 8	0.96101		R	Mechain.
1783	Nov. 19, 11 51	50 3 8	55 45 20	44 53 24	1.45440	0.5395345	D	Burckhardt.
—	Nov. 19, 13 30	49 31 55	55 12 0	47 43 0	1.49532	0.6784	D	Burckhardt.
1784	Jan. 21, 4 47	80 44 24	56 49 21	51 9 12	0.70786		R	Mechain.
1785 I.	Jan. 27, 7 49	109 51 56	264 12 15	70 14 12	1.14340		D	Mechain.
— II.	April 8, 8 59	297 29 33	64 33 36	87 31 54	0.42730		R	Mechain.
1786 I.	Jan. 30, 20 58	156 38 0	334 8 0	13 36 0	0.33482	0.84836	D	Encke.
— II.	July 7, 21 51	159 25 36	194 22 40	50 54 28	0.41010		D	Mechain.
1787	May 10, 19 49	7 44 9	106 51 35	48 15 51	0.34891		R	Saron.

Year of Appearance.	Greenwich Mean Time of Perihelion Passage.	Longitude of Perihelion.	Ascending Node.	Inclination.	Perihelion Distance.	Excentricity.	Motion.	Calculator.
A.D.	D. H. M.	° ′ ″	° ′ ″	° ′ ″				
1788 I.	Nov. 10, 7 25	99 8 7	156 56 43	12 27 40	1.06301		R	Mechain.
— II.	Nov. 20, 7 16	22 49 54	352 24 26	64 30 24	0.75731		D	Mechain.
1790 I.	Jan. 15, 5 6	60 14 32	176 11 46	31 54 15	0.75810		R	Saron.
—	Jan. 16, 18 58	58 24 45	172 50 2	29 44 7	0.74734		R	Saron.
— II.	Jan. 28, 7 36	111 44 37	267 8 37	56 58 13	1.06329		D	Mechain.
— III.	May 21, 5 47	273 43 27	33 11 2	63 52 27	0.79796		R	Mechain.
1792 I.	Jan. 13, 13 35	36 29 42	190 46 15	39 46 55	1.29301		R	Mechain.
— II.	Dec. 27, 6 5	135 59 24	283 15 17	49 1 45	0.96629		R	Prosperin.
1793 I.	Nov. 4, 20 12	228 42 0	108 29 0	60 21 0	0.40340		R	Saron.
— II.	Nov. 28, 14 24	75 58 58	359 4 48	47 35 5	1.40003	0.7347635	D	Burckhardt.
—	Nov. 28, 5 6	71 54 3	2 0 12	51 31 10	1.49512	0.9734211	D	D'Arrest.
1795	Dec. 21, 10 35	156 41 20	334 39 22	13 42 30	0.33443	0.8488828	D	Encke.
1796	April 2, 19 48	192 44 13	17 2 16	64 54 33	1.57816		R	Olbers.
1797	July 9, 2 31	49 27 8	329 15 37	50 40 34	0.52661		R	Olbers.
1798 I.	April 4, 11 32	104 59 0	122 9 0	43 52 16	0.48476		D	Burckhardt.
— II.	Dec. 31, 13 17	34 27 27	249 30 30	42 26 4	0.77952		R	Burckhardt.
1799 I.	Sept. 7, 5 39	3 39 46	99 32 47	50 56 27	0.83994		R	Burckhardt.
— II.	Dec. 25, 21 31	190 20 12	326 49 11	77 1 38	0.62580		R	Mechain.
1801	Aug. 8, 13 23	183 49 0	44 28 0	21 20 0	0.26170		R	Burckhardt
1802	Sept. 9, 21 23	332 9 4	310 15 39	57 0 47	1.09411		D	Olbers.
1804	Feb. 13, 15 31	148 53 32	176 49 47	56 44 20	1.07228		D	Bouvard.
1805	Nov. 21, 12 0	156 47 24	334 20 10	13 33 30	0.34042	0.8461753	D	Encke.

1806	Jan. 1, 23 23	109 32 23	251 15 15	13 38 45	0.90680	0.7457842	D	Gambart.
1806 II.	Dec. 28, 22 21	97 2 3	322 19 15	35 2 50	1.08157		R	Burckhardt.
1807	Sept. 18, 17 44	270 54 42	266 47 11	63 10 28	0.64612	0.9954878	D	Bessel.
1808 I.	May 12, 22 52	69 12 57	322 58 36	45 43 7	0.38986		R	Encke.
— II.	July 12, 4 1	252 38 50	24 11 15	39 18 59	0.60795		R	Bessel.
—	July 12, 5 16	252 31 39	24 27 33	39 17 24	0.60731		R	Hind.
1810	Oct. 5, 19 45	63 9 10	308 53 4	62 46 17	0.96914		D	Bessel.
1811 I.	Sept. 12, 5 53	75 1 9	140 24 30	73 2 36	1.03541	0.9954056	R	Bessel.
—	Sept 12, 6 11	75 0 34	140 24 44	73 2 21	1.03543	0.9950933	R	Argelander.
—	Sept. 12, 5 52	75 0 0	140 24 26	73 2 43	1.03559	0.9950827	R	Conti.
— II.	Nov. 10, 23 46	47 27 27	93 1 52	31 17 11	1.58211	0.9827109	D	Nicolai.
1812	Sept. 15, 7 32	92 18 44	253 1 2	73 57 3	0.77714	0.9545412	D	Encke.
1813 I.	March 4, 12 38	69 56 8	60 48 24	21 13 33	0.69913		R	Nicollet.
— II.	May 19, 10 3	197 43 46	42 40 40	81 2 28	1.21610		R	Encke.
1815	April 25, 23 49	149 1 56	83 28 34	44 29 55	1.21286	0.9312197	D	Bessel.
—	April 25. 23 50	149 1 58	83 28 36	44 29 52	1.21293	0.9316693	D	Nicolai.
1816	March 1, 8 18	267 35 33	323 14 56	43 5 26	0.04850		D	Burckhardt.
1818 I.	Feb. 25, 23 1	182 45 22	70 26 11	89 43 48	1.19777		D	Encke.
— II.	Dec. 4, 22 26	101 55 2	89 59 53	63 5 29	0.85509		R	Rosenberger.
1819 I.	Jan. 27, 6 9	156 59 12	334 33 19	13 36 54	0.33526	0.8485841	D	Encke.
— II.	June 27, 17 11	287 5 54	273 42 52	80 44 44	0.34101		D	Bouvard.
— III.	July 18, 21 36	274 40 51	113 10 46	10 42 48	0.77364	0.7551904	D	Encke.
— IV.	Nov. 20, 5 54	67 18 48	77 13 57	9 1 16	0.89256	0.6867458	D	Encke.
1821	March 21, 12 53	239 29 25	48 40 56	73 33 7	0.09182		R	Rosenberger.
1822 I.	May 5, 14 33	192 43 51	177 26 56	53 37 24	0.50442		R	Nicollet.
— II.	May 23, 23 7	157 11 44	334 25 9	13 20 17	0.34597	0.8444643	D	Encke.
— III.	July 16, 12 45	218 32 56	97 40 3	38 12 39	0.83672		R	Heiligenstein.

Year of Appearance.	Greenwich Mean Time of Perihelion Passage.	Longitude of Perihelion.	Ascending Node.	Inclination.	Perihelion Distance.	Excentricity.	Motion.	Calculator.
A.D.	D. H. M.	° ′ ″	° ′ ″	° ′ ″				
1822 IV.	Oct. 23, 18 28	271 40 17	92 44 42	52 39 10	1.14507	0.9963021	R	Encke.
1823	Dec. 9, 10 39	274 34 30	303 3 0	76 11 57	0.22650		R	Encke.
1824 I.	July 11, 12 19	260 16 32	234 19 9	54 34 19	0.59126		R	Rümker.
— II.	Sept. 29, 1 24	4 31 7	279 15 39	54 36 59	1.05014	1.0017345	D	Encke.
—	Sept. 29, 1 36	4 32 6	279 16 44	54 35 32	1.04983		D	Encke.
1825 I.	May 30, 13 9	273 55 1	20 6 8	56 41 6	0.88912		R	Clausen.
— II.	Aug. 18, 17 4	10 14 25	192 56 10	89 41 47	0.88347		D	Clausen.
— III.	Sept. 16, 6 33	157 14 31	334 27 30	13 21 24	0.34485	0.8448885	D	Encke.
— IV.	Dec. 10, 16 22	318 46 41	215 43 14	33 32 39	1.24084	0.9953690	R	Hansen.
1826 I.	March 18, 9 54	109 45 50	251 28 12	13 33 51	0.90252	0.7465727	D	Santini.
— II.	April 21, 23 4	116 54 40	197 38 9	40 2 33	2.01114		D	Clausen.
— III.	April 29, 0 56	35 48 13	40 29 13	5 17 2	0.18812		R	Clüver.
— IV.	Oct. 8, 22 51	57 48 24	44 6 28	25 57 18	0.85281		D	Argelander.
— V.	Nov. 18, 9 54	315 31 34	235 7 44	89 22 10	0.02689		R	Clüver.
1827 I.	Feb. 4, 22 7	33 30 16	184 27 49	77 35 35	0.50652		R	Heiligenstein.
— II.	June 7, 20 9	297 31 42	318 10 28	43 38 45	0.80815		R	Heiligenstein.
— III.	Sept. 11, 16 38	250 57 12	149 39 11	54 4 42	0.13784	0.99927305	R	Clüver.
1829	Jan. 9, 17 54	157 17 53	334 29 32	13 20 34	0.34554	0.8446245	D	Encke.
1830 I.	April 9, 7 15	212 11 22	206 21 35	21 16 5	0.92145	0.9993883	D	Hädenkamp and Mayer.
—	April 9, 7 13	212 11 44	206 21 52	21 16 28	0.92145		D	
— II.	Dec. 27, 15 51	310 59 19	337 53 7	44 45 30	0.12589		R	Wölfers.

1832 I.	May 3, 23 25	157 21 1	334 32 9	13 22 9	0.34347	0.8454141	D	Encke.
— II.	Sept. 25, 12 31	227 55 36	72 26 42	43 18 3	1.18360		R	E. Bouvard.
— III.	Nov. 26 2 53	110 0 55	248 15 36	13 13 1	0.87902	0.7514682	D	Santini.
1833	Sept. 10, 4 28	222 51 17	323 0 51	7 21 2	0.45842		D	Peters.
1834	April 2, 15 55	276 33 49	226 48 52	5 56 52	0.51503		D	Petersen.
1835 I.	March 27, 13 50	207 42 55	58 19 46	9 7 39	2.04130		R	W. Bessel.
— II.	Aug. 26, 8 40	157 23 29	334 34 59	13 21 15	0.34444	0.8450356	D	Encke.
— III.	Nov. 15, 22 32	304 31 32	55 9 59	17 45 5	0.58657	0.9673909	R	Westphalen.
1838	Dec. 19, 0 18	157 27 4	334 36 41	13 21 28	0.34404	0.8451775	D	Encke.
1840 I.	Jan 4, 10 14	192 11 50	119 57 46	53 5 32	0.61845	1.0002050	D	Peters and O. Struve.
— II.	March 12, 23 47	80 18 10	236 49 6	59 13 20	1.22139	0.9978836	R	Plantamour.
—	March 13, 2 56	80 12 4	236 50 35	59 12 36	1.22045	0.9932341	R	Loomis.
— III.	April 2, 12 54	324 20 24	186 4 24	79 51 24	0.74205		D	Petersen.
— IV.	Nov. 13, 15 28	22 31 40	248 56 22	57 57 23	1.48083	0.9698526	D	Götze.
1842 I.	April 12, 0 26	157 29 27	334 39 10	13 20 26	0.34501	0.8447904	D	Encke.
— II.	Dec. 15, 22 58	327 17 32	207 49 39	73 34 4	0.50443		R	Petersen.
1843 I.	Feb. 27, 9 47	278 39 51	1 12 24	35 41 9	0.005579	0.9998929	R	Hubbard.
—	Feb. 27, 10 19	278 36 33	1 37 55	35 36 29	0.005584		R	Nicolai.
— II.	May 6, 0 34	281 27 48	157 14 51	52 44 1	1.61583		D	Götze.
—	May 6, 1 21	281 29 43	157 14 54	52 44 46	1.61634	1.0001798	D	Götze.
— III.	Oct. 17, 3 33	49 34 19	209 29 19	11 22 31	1.69258	0.5559623	D	Le Verrier.
—	Oct. 16, 21 11	49 22 46	209 32 8	11 22 33	1.69026	0.5562639	D	Nicolai.
—	Oct. 16, 21 53	49 24 16	209 31 59	11 22 40	1.69075	0.5565054	D	Hind.
1844 I.	Sept. 2, 11 23	342 30 50	63 49 0	2 54 50	1.18640	0.6176539	D	Brünnow.
—	Sept. 2, 11 28	342 31 15	63 49 31	2 54 45	1.18630	0.6172559	D	Faye.
— II.	Oct. 17, 8 15	180 24 3	31 39 5	48 36 1	0.85539	0.9996083	R	Plantamour.

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A.D.	D H. M.	° ′ ″	° ′ ″	° ′ ″				
1844 II.	Oct. 17, 8 4	180 24 10	31 39 5	48 36 22	0.85530		R	Hind.
—III.	Dec. 13, 16 23	296 0 32	118 23 24	45 36 34	0.25126		D	Hind.
1845 I.	Jan. 8, 3 44	91 19 39	336 44 30	46 50 30	0.90519		D	Götze.
— II.	April 21, 0 45	192 33 19	347 6 45	56 23 36	1.25468		D	Faye.
—III.	June 5, 16 10	262 2 56	337 48 56	48 41 59	0.40162	0.9898742	R	D'Arrest.
—	June 5, 16 24	262 0 33	337 48 49	48 55 8	0.40108		R	D'Arrest.
— IV.	Aug. 9, 15 2	157 44 21	334 19 33	13 7 34	0.33814	0.8474362	D	Encke.
1846 I.	Jan. 22, 2 15	89 6 22	111 8 26	47 26 6	1.48070	0.9924026	D	Jelinek.
— II.	Feb. 10, 23 42	109 2 20	245 54 39	12 34 53	0.85645	0.7570030	D	Plantamour.
—III.	Feb. 25, 7 57	116 28 24	102 37 41	30 57 51	0.65004	0.794460	D	Hind.
—	Feb. 25, 8 59	116 28 15	102 40 58	30 55 53	0.65010	0.7933880	D	Brünnow.
— IV.	March 5, 12 8	90 27 19	77 33 26	85 6 12	0.66374	0.9622465	D	Peirce.
—	March 5, 13 6	90 27 0	77 33 33	85 5 43	0.66365	0.9620891	D	Van Deinse.
— V.	May 27, 21 57	82 32 57	161 18 49	57 35 50	1.37627		R	Argelander.
— VI.	June 1, 2 31	239 49 51	260 12 25	31 2 14	1.53766	0.7567235	D	D'Arrest.
—	June 1, 5 6	240 7 35	260 28 59	30 24 24	1.52872	0.7213385	D	Peters.
—VII	June 5, 12 26	162 0 54	261 51 14	29 18 47	0.63344	0.9883605	R	Wichmann.
—VIII	Oct. 29, 17 56	98 35 50	4 41 4	49 41 17	0.83062		D	Hind.
1847 I.	March 30, 6 28	276 11 50	21 49 31	48 39 49	0.042014		D	Hind.
— II.	June 4, 16 34	141 37 10	173 57 40	79 33 43	2.11513		R	Gautier.
—III.	Aug. 9, 8 17	21 17 30	76 43 23	32 38 47	1.48479		R	Schweizer.
— IV.	Aug. 9, 10 37	246 41 34	338 17 31	83 27 1	1.76717		R	Littrow.

1847 V.	Sept. 9, 13 2	79 12 6	309 48 49	19 8 25	0.48790	0.9725602	D	D'Arrest.
— VI.	Nov. 14, 4 14	274 26 11	190 55 56	72 10 51	0.32999		R	G. Rümker.
1848 I.	Sept. 8, 1 6	310 34 39	211 32 29	84 24 50	0.31993		R	Sonntag and Quirling.
— II.	Nov. 26, 2 46	157 47 8	334 22 12	13 8 36	0.33703	0.8478280	D	Encke.
1849 I.	Jan. 19, 8 21	63 14 15	215 12 54	85 2 54	0.95973		D	Petersen.
— II.	May 26, 11 54	235 43 24	202 32 56	67 9 39	1.15932		D	Weyer.
— III.	June 8, 4 10	267 3 16	30 31 48	66 59 2	0.89466	0.9978300	D	D'Arrest.
—	June 8, 4 53	267 6 8	30 32 0	66 55 19	0.89439		D	Schweizer.
1850 I.	July 23, 12 28	273 23 58	92 52 56	68 12 8	1.08151		D	Sonntag.
— II.	Oct. 19, 8 10	89 13 54	205 59 24	40 5 37	0.56546		D	Vogel.
1851 I.	April 3, 11 55	49 42 40	209 30 35	11 21 40	1.69996	0.5550192	D	Le Verrier.
— II.	July 8, 16 48	322 59 46	148 27 20	13 56 12	1.17398	0.6608815	D	D'Arrest.
— III.	Aug. 26, 7 20	311 12 52	223 9 17	37 43 57	0.98136		D	Vogel.
— IV.	Sept. 30, 19 12	338 45 18	44 25 37	73 59 44	0.14132		D	Sonntag.
1852 I.	March 14, 18 58	157 51 2	334 23 21	13 7 54	0.33745	0.8476726	D	Encke.
— II.	April 19, 13 52	280 0 33	317 8 22	48 52 54	0.90502		R	Sonntag.
— III.	Oct. 12, 15 6	43 12 16	346 13 25	40 58 32	1.25103	0.924753	D	Marth.

NOTES

TO THE

CATALOGUE OF COMETARY ORBITS.

B.C.

370. Elements assigned by Pingré from the account given by Aristotle.

136. The orbit of this comet is founded upon the Chinese observations which have recently become known in Europe. Like most of those which follow, and are based upon the Chinese records, it is necessarily open to a good deal of uncertainty.

68. From Chinese observations.

11. Elements assigned on the supposition of the identity of this comet with that now known as Halley's. The orbit given in the American Almanac for 1847, and copied into Encke's recent edition of Olbers' Abhandlung, will not represent the observations as published in M. Biot's Catalogue.

A.D.

66. The few circumstances related by the Chinese respecting this comet, may be represented either by the orbit in the Catalogue, or by carrying back the elements of Halley's comet to the epoch.

141. From Chinese observations. The similarity between the elements of this comet and that of 1066 is pretty certain—probably an appearance of the comet of Halley.

240. Chinese observations. The elements somewhat doubtful.

539. Chinese observations.

565. Chinese observations on two different suppositions respecting the comet's distance from the earth, at the first and third observations.

568. Also founded upon the Chinese records. It is perhaps, however, the most certain orbit deduced from these authorities, as the comet approached very near the earth, and was observed several months.

574. Chinese observations: the elements are open to much uncertainty.

770. Chinese observations: rather uncertain, but the general character of the orbit is decided.

837. These elements belong to the first or grand comet of this year: they appear to represent the observations, Chinese and European, as well as could be reasonably expected.

961. The observations of this comet, recorded in the Chinese annals, are amply sufficient to give a very fair idea of the real path in space.

989. Chinese observations: probably an appearance of Halley's comet.

1066. The famous comet which astonished Europe in the year of the Norman conquest; very likely the comet of Halley, which was due about this epoch; —the orbit assigned is very similar.

1092., 1097. From the Chinese observations.

1231. Calculated by Pingré on the European and Chinese records. We find there is a great likeness between the elements of this comet and those calculated for the comet of 1746, observed only by Kindermanns.

1264. A grand comet, supposed to be identical with that of 1556. Pingré's is the most satisfactory orbit. Mr. Dunthorne's depends on a recital by Friar Giles, of Cambridge, containing several manifest contradictions.

1299. Chinese observations.

1301. Probably an appearance of Halley's comet. M. Laugier has been led to a different orbit, from including two observations purporting to have been taken by Friar Giles, at Cambridge; but there is some doubt respecting them.

1337. A very fine comet, and the first which appears on Halley's list, in his *Synopsis of Cometary Astronomy.* The elements there given were founded upon the particulars related of this body by Nicephoras Gregoras, the Byzantine historian. The Chinese annals, more recently known in Europe, contain a more decisive account, and it is upon this authority that the orbits of Pingré, Laugier, and the author, have been computed.

1351. A few Chinese observations without latitudes. Very uncertain.

1362.
1366. Chinese observations; uncertain, particularly in 1366.

1385. Chinese observations; but they are sufficiently definite to give a general notion of the orbit.

1433. Chinese observations: tolerably certain.

1456. The celebrated comet of Halley. The elements are partly adapted to the observations left by Eben-

dorffer and others. The comet was observed also in China.

1457. European observations—a mere approximation. It appears certain that the perihelion distance was far greater than in the case of any other ancient comet.

1468. Chinese observations; but the orbit must be open to a good deal of uncertainty.

1472. One of the most splendid comets recorded in history. M. Laugier's elements are based upon a minute recital of particulars relating to the motion and positions of the comet, found in the Chinese annals. It approached very near the earth, and the plane of its orbit appears to have been nearly coincident with that of the ecliptic.

1490. Chinese observations. The elements have some resemblance to those of the comet found by Bremicker, in October, 1840, and which, according to Götze's calculation, should have appeared at the latter end of the fifteenth century; but it does not appear easy to reconcile the observations of 1490 with the elements of the comet of 1840—probably the bodies were not identical.

1506. Chinese observations: elements somewhat uncertain.

1531. The comet of Halley, observed in this year by Peter Apian, at Ingoldstadt; and likewise in China.

1532. It is still uncertain whether this comet is identical with that observed by Hevelius in 1661. The elements of Halley and Olbers are very like those of the comet of 1661; but Mechain, who discussed this question at considerable length, gives an orbit materially different. It was not re-

observed about the year 1790, as anticipated by most astronomers.

1533. There is no comet whose elements are subject to greater doubt than that seen by Apian in 1533, as a comparison of the results of Olbers and Douwes will prove. Both orbits, according to Olbers, represent the few observations recorded, and it appears impracticable at present to decide between them.

1556. Generally supposed to be a re-appearance of the great comet of 1264. The elements calculated by the author are the results of a close examination of the observations of Fabricius and others, and appear to represent all the circumstances recorded of the comet with sufficient accuracy.

1558. From the observations of the Landgrave of Hesse and Cornelius Gemma.

1577. The elements of this comet were first calculated by Halley; but the orbit given in the Catalogue is the result of a new discussion of Tycho Brahe's observations, by Dr. Woldstedt.

1580. This comet was roughly observed by Tycho Brahe; the positions are frequently uncertain to ten minutes of arc, and the elements are consequently somewhat doubtful. Halley also computed an orbit upon Mæstlin's observations.

1582. Three observations only by Tycho. The elements are uncertain, but the first set is to be preferred.

1585. Both orbits have been recently computed, in order to decide the question of the identity of this comet with that found by M. de Vico, in August, 1844. Dr. Peter's elaborate paper upon the comet is published in the *Astronomische Nachrichten.* The observations of Tycho Brahe and Rothmann are

perfectly represented by a parabola; and according to Le Verrier, there is no probability in favour of the identity.

1590. Founded upon Tycho's observations, which were reduced anew by the author.

1593. From the observations of Ripensis at Zerbst.

1596. The elements have been recently calculated by M. Valz and the author, in consequence of an apparent similarity between the comet of 1596 and that of June, 1845. Halley had previously calculated the elements upon Mæstlin's observations, and M. Pingré upon Tycho's. Both the new determinations are founded upon the details left by the Danish astronomer.

1607. The celebrated comet of Halley.

1618. (I.) Pingré's orbit depends upon the somewhat imperfect observations of Kepler.

1618. (II.) This splendid comet was one of the finest ever observed. The elements were calculated by Bessel from the observations of Harriot, Longomontanus, and others. Halley had previously determined the orbit.

1652. A fine comet observed by Hevelius. It would be worth while to reduce his observations more accurately, and work out another set of elements.

1661. Formerly supposed to be identical with the comet of 1532; but this is now doubted. Halley first assigned elements in his *Synopsis of Cometary Astronomy*. Mechain's will be more exact. Observed by Hevelius.

1664.
1665. The orbits of these fine comets were calculated by Halley from the observations of Hevelius. Lubienietski wrote a folio volume upon them, in which are found many observations, inferior, however, in accuracy to those of Hevelius.

1668. Calculated from the positions laid down in a chart of the comet's path in the heavens, by Father F. de Gottignies, of Goa. This has been supposed to be identical with the grand comet of March, 1843. The elements are very uncertain. Either of the orbits given in the Catalogue will represent approximately the apparent track of the comet. The chart has been re-published at Rome, under the title—'Estratto delle osservazioni fatte sulla Cometa del 1668.'

1672. }
1677. } From the observations of Hevelius at Dantzic.

1678. Observed roughly by Lahire at Paris. It is considered to have been an appearance of the periodical comet of De Vico by Le Verrier, who has shown that elements closely approaching those of that body will satisfy all the particulars recorded of the comet in 1678. These elements are given in the preceding table.

1680. The celebrated comet which led Newton to the study of cometary astronomy. The elements in the Catalogue are the results of Encke's masterly investigation, published in the *Zeitschrift für Astronomie*, 1818.

1682. The comet of Halley. Rosenberger's last orbit, in which perturbations are taken into account.

1683. Elliptic elements computed by Clausen from a new reduction of Flamsteed's observations at our Royal Observatory. The periodic time found by this astronomer is 190 years; but little dependence can be placed upon a result of this kind.

1684. Observed by Bianchini at Rome.

1686. Observed in Europe in September, but previously (in August) in the East Indies.

1689. A fine comet observed very roughly by Father Richaud at Pondicherry; and by Bèze and Comille at Malacca, &c.

1695. Observed still more imperfectly than that of 1689, in the southern hemisphere. The elements were calculated by Burckhardt, upon manuscript observations preserved in the Depôt de la Marine at Paris.

1698. Somewhat roughly observed by Lahire and Cassini at Paris. Halley does not give the orbit with much confidence.

1699. Observed by Cassini and Maraldi at Paris, and by Fontenay at Pekin.

1701. Calculated by Burckhardt from the observations of Fathers Pallu and Thomas, at Pau and Pekin respectively.

1702. Observed in April and May at Paris, Berlin, and Rome, but not very accurately. The inclination of the orbit is very small.

1706. Observed at Paris by Cassini and Maraldi.

1707. Found at Bologna by Manfredi and Stancari on November 25, and four days later by Cassini and Maraldi at Paris. If this comet had reached its perihelion about fourteen days later, it would have passed very near the earth at the end of October.

1718. From Kirch's observations, which Argelander has reduced anew.

1723. Discovered first at Bombay on October 12th; and observed after the 20th in England by Halley, Bradley, and Pound, and in various other parts of Europe. The orbit has been recently calculated by Spörer, from a new reduction of the observations.

1729. Discovered by Father Sarabat at Nismes, on July 31, and observed until the 18th of January, 1730.

The orbit is remarkable for the enormous perihelion distance, far exceeding that of any other comet hitherto calculated. The first orbit is hyperbolic.

1737. (I.) Observed and calculated by Bradley. Also by Cassini at Paris, and Manfredi at Bologna. The comet appears to have been first seen at Spanish-town, Jamaica, on the 6th of February.

1737. (II.) Observed at Pekin, but only approximately.

1739. Chiefly observed by Zanotti at Bologna, where it was discovered on the 28th of May.

1742. Seen in all parts of Europe, but first detected at the Cape of Good Hope on the 5th of February.

1743. (I.) Very imperfectly observed, after the 10th of February, at Berlin, Paris, Bologna, and Vienna. Clausen thought this comet might be identical with the fourth of 1819. His calculations assign a period of about 5½ years.

1743. (II.) Observed only by Klinkenberg, at Haarlem, after August 18th. The positions given are liable to considerable errors.

1744. The finest comet of the eighteenth century. The elements have been calculated by a great number of astronomers, but those we have given in the Catalogue appear entitled to most reliance. The comet was discovered by Klinkenberg, at Haarlem, on the 9th of December, 1743.

1746. Calculated by the author from the rough indications afforded by Kindermanns, who, strangely enough, appears to have been the only observer of this comet. It must have passed very near the earth. The similarity between the elements of the comets of 1231 and 1746 is striking.

1747. Discovered by Cheseaux, at Lausanne, in Switzerland, August 13th, 1746, and observed only in that

year; but the perihelion passage did not take place until March, 1747.

1748. (I.) Observed by Maraldi at Paris, and by Bradley at Greenwich; also at Pekin. The positions determined at our Royal Observatory may perhaps lead to a more exact orbit. As far as we are aware, they have not as yet been thoroughly discussed.

1748. (II.) Three observations only, by Klinkenberg, at Haarlem, reduced and calculated by Bessel.

1757. Bradley's are undoubtedly the best observations of this comet: they extend from September 13th to October 18th, and are well represented by a parabolic orbit, notwithstanding the small angle of inclination and direct motion.

1758. Discovered by La Nux, at the Isle of Bourbon, on the 26th of May, and observed in Europe till the 2nd of November. The orbit depends on the observations of Messier at Paris.

1759. (I.) The famous comet of Halley; its first predicted reappearance: was discovered by a Saxon farmer, named Palitzch, on the 25th of December, 1758, but not generally observed until April following. The elements are the results of the masterly calculations of Rosenberger and Lehmann, and apply to the moment of perihelion passage, the effects of planetary perturbations being taken into account.

1759. (II.) Discovered by Messier, January 25th, 1760, in Leo. Perihelion passage in the previous year.

1759. (III.) First seen at Lisbon on January 7th, and very generally observed on the following night. The comet approached near the earth, and its apparent motion was unusually rapid. On the 8th of January it was moving at the rate of 29° of a great circle daily.

1762. Detected by Klinkenberg May 17th, and observed until the beginning of July. The elements, like those of most comets of the eighteenth century, have been calculated by many astronomers; but the best set is that of Burckhardt, given in the Catalogue.

1763. Both our orbits are elliptic; in the first the period is 7334, and in the second 1137 years: these numbers are to be regarded merely as the results of calculation. Pingré says he spent more time over this comet than any of the others he had calculated, but could not arrive at any satisfactory conclusions. It was discovered at Paris, by Messier, on the 28th of September.

1764. Also detected by Messier, on the 3rd of January.

1766. (I.) Discovered by Messier on March 8th, and observed on the eight following days only.

1766. (II.) A remarkable comet, as exhibiting a deviation from parabolic motion. It was seen by Messier at Paris, on April 8th, and observed on the four following days, but had been previously discovered by Father Helfenzriede at Dillengen, on the 1st. La Nux observed it at the Isle of Bourbon, after perihelion passage, from April 29th to May 13th. The periodic time assigned by Burckhardt is 1835 days, or 5·025 years; but the comet has not been recognised at any subsequent time.

1769. A great comet discovered by Messier on the 8th of August, and observed until the 1st of December. Amongst the numerous astronomers who watched this comet was Dr. Maskelyne, of Greenwich, and his description is amply sufficient to convey a notion of its magnitude and splendour. The accounts furnished by Pingré and others, which give it even a more imposing aspect, have been already

noticed. Bessel's orbit is the result of an elaborate investigation published in 1808. He finds the most probable period 2090 years; but supposing errors of 5″ only in the observations employed, it may be extended to 2673 or diminished to 1692 years; hence the observations leave us in doubt as to the true period of the comet in 1769, to the extent of nearly 1000 years.

1770. (I.) The celebrated comet of 1770: discovered by Messier on the 14th of June. At the beginning of July it approached very near the earth. Burckhardt, Clausen, and Le Verrier, have distinguished themselves by their investigations relative to this comet. The latest results are those of Le Verrier, which were obtained at a vast expense of time and labour, such as few but that eminent mathematician and astronomer would have had the courage to meet.

1770. (II.) This comet did not appear till January, 1771, but the perihelion passage occurred in November, 1770. It was observed at Paris, at Milan, and at the Isle of Bourbon by La Nux.

1771. Discovered by Messier, at Paris, on April 1st. Of all the comets hitherto observed, that of 1771 affords the most decisive indications of *hyperbolic* motion. Encke found it impossible to represent the observations within their probable limits of error by any other curve, a conclusion previously arrived at by Burckhardt.

1772. The first recorded appearance of the *Comet of Biela*. Bessel *assumed* a periodic time of 33 years, and adapted the other elements accordingly. Gauss' orbit was obtained by direct calculation.

1773. Discovered by Messier on the 12th of October,

and observed for six months. Burckhardt found no sensible deviation from a parabola.

1774. Detected at Limoges by Montaigne, on August 11th. Burckhardt's elements are *hyperbolic*, and depend upon Messier's observations of September 20th, October 8th and 25th.

1779. Discovered by Bode at Berlin, on the 6th of January, and also by Messier at Paris, on the 18th, without previous knowledge of Bode's observations. Many orbits have been calculated: Prosperin computed three—an ellipse, a parabola, and a hyperbola. Zach's elements, which we have entered in the Catalogue, are probably amongst the most exact.

1780. (I.) Discovered by Messier, on the 26th of October. Clüver recalculated the orbit at the request of Dr. Olbers, with the view of ascertaining if there were any probability in favour of a presumed identity of this comet with the third of 1827; but notwithstanding the striking similarity in the elements, this does not appear likely, as the observations are well represented by a parabola. The period in Clüver's ellipse is 75,320 years!

1780. (II.) Detected on the same day, October 18th, by Montaigne and Olbers, in Ophiuchus, and but very imperfectly observed on three days only. The orbit is therefore somewhat uncertain.

1781. (I.) Found by Mechain on the 28th of June.

1781. (II.) Also discovered by Mechain, at Paris, on October 9th, near δ Cancri. It was visible to the naked eye, and approached pretty near the earth. Mechain's elements satisfy all the observations well.

1783. Discovered by our countryman, Pigott, at York,

on the 19th of November. The comet exhibits decided indications of elliptic motion. The period assigned by Burckhardt is 5·613 years, but this may probably be improved upon by a rigorous discussion of the observations, which appears very desirable.

1784. First seen by La Nux, at the Isle of Bourbon, on December 15th, 1783, and found at Paris on the 24th of the following month. Last observed on May 26th.

1785. (I.) Found by Messier and Mechain, on January 7th.

1785. (II.) Discovered by Mechain, on March 11th.

1786. (I.) Found on the 17th January, by the same diligent astronomer. It is the first observed appearance of the comet of Encke. Only two observations were procured.

1786. (II.) Discovered by Miss Caroline Herschel, sister of Sir William Herschel, on August 1st, and observed till the 26th of October.

1787. Found April 10th, by Mechain, at Paris.

1788. (I.) Detected by Messier, on November 25th.

1788. (II.) The second comet discovered by Miss Herschel, at Slough, near Windsor, December 21st.

1790. (I.) Also discovered by the same lady on the 7th of January, but only imperfectly observed on four occasions: the elements are consequently merely approximate.

1790. (II.) Perceived by Mechain, on January 9th, two days after Miss Herschel's discovery of the first comet of 1790.

1790. (III.) Discovered at Slough, by Miss Herschel, April 17th, and observed till the end of June.

1792. (I.) Discovered on the 15th of December, 1791, by Miss Herschel, but the perihelion passage did not take place till the following year.

1792. (II.) Discovered by Mechain and Piazzi, on the 10th of January, 1793; the perihelion occurring in the previous year.

1793. (I.) Discovered by Messier, on September 27th, and last seen on January 7th, 1794.

1793. (II.) A remarkable comet discovered by Perny, on the 24th of September. Burckhardt assigns a period of 12·13 years, and leaves it doubtful whether this comet was identical with that of 1783 or not. Dr. D'Arrest, of Leipzig, has recently reduced the observations anew, and finds the orbit given in the table: period 422 years.

1795. *The Comet of Encke*, detected at this appearance on the 7th of November, by Miss Caroline Herschel, at Slough.

1796. Discovered by Olbers, at Bremen, on the 31st of March.

1797. A rather conspicuous comet, discovered nearly simultaneously, on August 14th, by Bouvard at Paris, Miss Herschel at Slough, and by Mr. S. Lee at Hackney.

1798. (I.) Discovered by Messier, April 12th.

1798. (II.) Found at Paris, by Bouvard, on December 6th; and at Bremen, by Olbers, on the 8th; it was not seen after the 12th, so that the orbit is not very accurately determined.

1799. (I.) Discovered by Mechain, on August 6th.

1799. (II.) Also discovered by the same astronomer, on the 26th of December, and observed for ten days. Mechain thought it might be identical with the comet of 1699, but the inclinations differ considerably.

1801. Discovered almost simultaneously by Pons, at Marseilles, and by Messier, Mechain, and Bouvard, at

Paris, on the 12th of July, in Camelopardus. The observations are not very exact.

1802. Discovered by Pons, on August 26th, in Ophiuchus, and two days subsequently by Mechain

1804. Discovered by Pons, on March 7th, and observed for about three weeks. Bouvard found it on the 10th, and Olbers on the 12th. It was situate in the constellation Virgo.

1805. The third appearance of *Encke's Comet.* Discovered on the same morning, October 21st, by Pons at Marseilles, Bouvard at Paris, and Huth at Frankfort, in Ursa Major: it was then visible without the telescope.

1806. (I.) The second appearance of *Biela's Comet.* Discovered by Pons, on the 10th of November, 1805. It became visible to the naked eye.

1806. (II.) Discovered by Pons, November 10th, and last seen on the 12th of February, 1807.

1807. The Great Comet of this year was found at Castro Giovanni, in Italy, by an Augustine monk, named Parisi, on the 9th of September, and eight days later by the indefatigable Pons, at Marseilles. It was observed until the 27th of March, 1808. Bessel's elements are the result of a masterly investigation, in which all the observations deserving of confidence were included. The periodic time assigned by this astronomer is 1714 years.

1808. (I.) Discovered by Pons on March 25th, and by Wisniewsky, at St. Petersburg, on the 29th, near the north pole of the heavens, in Camelopardus.

1808. (II.) Also discovered by Pons, June 24th, and roughly observed for ten days at Marseilles. The elements, though more than sufficient to identify

the comet if it should re-appear, are not very exactly ascertained.

1810. Discovered on August 22nd, by Pons, in Camelopardus, but only approximately observed, the right ascensions exhibiting material errors, according to Bessel's comparison with his elements.

1811. (I.) The Grand Comet. We have already given a particular account of this splendid comet, which was first perceived by Flaugergues, at Viviers, on the 26th of March, and observed till the 17th of August, 1812, by Wisniewsky, at Neu-Tscherkask. Many ellipses have been calculated, in all of which the period extends to more than 3000 years. Bessel's orbit was corrected by Argelander, whose results deserve the greatest confidence.

1811. (II.) Another fine, though much less conspicuous comet, discovered by Pons, on the 16th of November, in Columba, and observed for three months. Nicolai has thoroughly discussed the observations, and assigns a periodic time of 875 years.

1812. Discovered by Pons, on the 20th of July, in Lynx. Encke has assigned elliptical elements, the period being 70·68 years. Early in September the comet was distinctly visible to the naked eye. It was seen till the end of that month.

1813. (I.) Discovered by Pons, on the 4th of February.

1813. (II.) Discovered April 3rd, by Pons, at Marseilles, and by Harding at Göttingen. It became very bright, and visible to the naked eye.

1815. The *Comet of Olbers*, discovered by that great astronomer at Bremen, on March 6th, and last observed on the 26th of August. Bessel makes the periodic time, in 1815, 74·049 years, and Nicolai, 74·789 years; but the former having cal-

culated the perturbations onward to the next perihelion, finds that it will be expedited considerably, and will occur about February 9th, 1887.

1816. Discovered by Pons, at Marseilles, on the 22nd of January. There is only one accurate observation, taken at Paris on February 1; the others are merely approximate. The elements were communicated by Buckhardt, in a letter to Olbers, and have only recently appeared in print, through the instrumentality of Dr. D'Arrest.

1818. (I.) Discovered by Pons, on December 26th, 1817, but the perihelion passage occurred in the following year; it was considered by Pons the faintest of all the comets he had found. It was seen at Bremen till May 1st.

1818. (II.) Discovered by Pons, on November 29th, in Hydra; and by Bessel, on December 22nd, in Cygnus, without knowledge of the previous discovery. It moved very rapidly, and approached pretty near the earth. Rosenberger computed a hyperbolic orbit.

1819. (I.) A memorable appearance of the *Comet of Encke*, when its periodicity was detected, and since which its returns have been regularly predicted. It was discovered by Pons, on the 26th of November, 1818, but the perihelion did not take place till the end of January in the following year.

1819. (II.) The Great Comet. Discovered in various parts of Europe, on the 1st and 2nd of July, having made its appearance rather suddenly above the north-west horizon, in the constellation Lynx. A parabola satisfies all the observations well: they

extend to October 20th. The comet was distinctly visible to the naked eye, with a bright tail and nucleus.

1819. (III.) The first of two remarkable comets observed in this year, both of which exhibit every indication of elliptic motion in orbits of very short period. It was discovered by Pons on June 12, and observed till July 19th. Encke assigns a period of revolution of 2052 days, or 5·618 years.

1819. (IV.) Found by Blainpain, at Marseilles, on November 28th, and observed at Milan till the 25th of January, 1820. The orbit appears decidedly elliptical, and Encke makes the duration of a revolution 1757 days, or 4·810 years. Clausen thinks this comet may be identical with the first of 1743.

1821. Discovered by Pons, at La Marlia, near Lucca, and by Nicollet, at Paris, on the 21st of January; and subsequently at various other observatories. It was observed in Europe before the perihelion passage until March 7th, and was seen from April 1st to May 3rd, by Captain Basil Hall, at Valparaiso. The chief peculiarity of the orbit is the smallness of the perihelion distance.

1822. (I.) Discovered by Gambart, at Marseilles, on May 12th, by Pons on the 14th, and by Biela on the 16th: it was situate in Auriga. It was visible until the end of June.

1822. (II.) The first predicted reappearance of the *Comet of Encke*, which was found by Rümker, at Paramatta, New South Wales, on the 2nd of June, and observed till the end of the month. It was not seen in Europe.

1822. (III.) Found by Pons, at La Marlia, on the morning

of May 31st, in Pisces. Its apparent motion was very rapid, and it was soon lost below the horizon in Europe.

1822. (IV.) Discovered by Pons, on the 13th of July, in the constellation Cassiopea, and observed till October 22nd in Europe. Gambart saw the comet on July 16th. Ellipses have been calculated by Encke, and by Rümker from his own observations at Paramatta, extending to November 11th. The period given by Encke is 5444 years, while that assigned by Rümker is 1816 years. Encke's orbit is doubtless the most exact that has been computed.

1823. A fine comet, discovered in various parts of Europe, at the end of December, and observed till the end of March, 1824. This comet is remarkable as having exhibited a tail directed towards the sun, in addition to another in the usual position.

1824. (I.) Discovered at Paramatta, by Rümker, on the 15th of July, in Leo, and observed there until the 11th of the following month. It was not seen in Europe.

1824. (II.) Discovered at Chemnitz, by Scheithauer, on the 23rd of July, in Hercules; by Pons on the following day; and at later periods by Gambart and Harding. Observed at Naples till the 25th of December. The orbit was hyperbolic, according to Encke.

1825. (I.) Discovered by Gambart, at Marseilles, on May 19th, in Cassiopea; and last seen by Rümker, at Paramatta, on the 15th of July, in Leo. The elements resemble those of the third comet of 1790; but as the observations are well represented by a parabolic orbit, the comets can hardly be identical.

1825. (II.) Discovered by Pons, at Florence, on the 9th of August; and a fortnight later, by Harding, at Göttingen. It was last observed on August 26th, in Orion. The orbit is almost perpendicular to the plane of the ecliptic.

1825. (III.) *The Comet of Encke.* Found by Valz, at Nismes, July 13th, and subsequently observed at nearly all the observatories of Europe.

1825. (IV.) *The Great Comet of* 1825; or, as it was called at first, 'the Comet in Taurus.' It was found by Pons on the 15th, and by Biela on the 19th of July; was observed in Europe before the perihelion passage until the middle of October, when it had become bright, with a conspicuous tail; afterwards at Paramatta, by Rümker, till the 20th of December; and re-discovered in Europe at the beginning of April, and followed by the astronomers of Florence until the 8th of July. Hence the observed arc extends over a whole year—an unusually long period. Hansen calculated several elliptical orbits: that we have given is founded on observations considerably distant from each other. The periodic time is 4386 years. This, however, may possibly be corrected by a more rigorous investigation, but it is certain that the revolution extends to many centuries.

1826. (I.) The famous *Comet of Biela* which was recognised as a comet of short period at this appearance. It was found by Biela, at Josephstadt, on the 27th of February, and at Marseilles by Gambart, on the 9th of the following month. The orbit in the Catalogue is founded on a great number of observations.

1826. (II.) Discovered by Pons on November 7th, 1825,

in Eridanus, in which constellation it remained until finally lost sight of about April 11th. The orbit is chiefly remarkable for the great perihelion distance. It appears to differ in no material degree from a parabola.

1826. (III.) Discovered by Flaugergues, at Viviers, on the 29th of March, and observed by him only till the 6th of April. The comet approached very near to the earth, but notwithstanding this circumstance, the elements are open to great uncertainty. The discoverer calculated an orbit widely different from Clüver's, which, however, is undoubtedly most correct.

1826. (IV.) Discovered by Pons on August 7th, and a week later by Gambart. It was seen until the latter end of November. The path of this comet crosses the ecliptic at a point not very far distant from the earth's orbit.

1826. (V.) Discovered by Pons, October 22nd, by Clausen on the 26th, and by Gambart on the 28th. The comet passed over the sun's disc on the 18th of November, but was not seen at that time. It was observed until the first week in January, 1827.

1827. (I.) Discovered by Pons, on December 26th, 1826.

1827. (II.) Also discovered by Pons, on June 20th, and likewise by Gambart, at Marseilles. Continued visible about one month.

1827. (III.) Discovered by Pons, on August 2nd. It was at first supposed that this comet was identical with the first of 1780; but Clüver's elliptical orbit, which has a period of 2610 years, is against this idea. The true path in space appears to be very nearly a parabola. The comet was observed until the middle of October.

1829. *The Comet of Encke.* The perihelion passage falls in 1829; but the observations were made in the previous year. Struve detected it on September 16th, in Aries, and saw it until the 27th of December. At the end of November it was distinctly visible to the naked eye. The elements in the Catalogue are undoubtedly very exact.

1830. (I.) This comet was discovered in the southern hemisphere, on the 17th of March, and was then conspicuous to the naked eye, with a somewhat lengthy tail. Gambart found it on April 20th, and it was observed in Europe till the 17th of August. The best elements are those of Hădenkamp and Mayer, calculated chiefly upon the accurate observations taken by Bessel at Königsberg. The parabola is preferable to the ellipse.

1830. (II.) Discovered about the 7th of January, 1831, by several persons, without the telescope, and observed for two months. It exhibited a tail and bright nucleus.

1832. (I.) *The Comet of Encke.* Discovered on June 1st, by Mossotti, at Buenos Ayres, and on the following day by Henderson, at the Royal Observatory, Cape of Good Hope. Harding also saw it at Göttingen, on the 21st of August, but it was not observed elsewhere in Europe.

1832. (II.) Discovered by Gambart, at Marseilles, July 19, and ten days later by Harding. It was observed till the end of August.

1832. (III.) *The Comet of Biela.* Its first predicted reappearance. Discovered at the Collegio Romano, at Rome, on the morning of August 24th, and seen by Sir John Herschel about a month later; but it was not generally observed till October.

The last observation is by Henderson, at the Cape of Good Hope, on the 3rd of January, 1833. The best observations are those at Königsberg and Dorpat.

1833. Discovered by Dunlop, at Paramatta, New South Wales, at the end of September, in Libra, and observed only to the middle of October.

1834. Discovered by Gambart, at Marseilles, on March 7th, and a fortnight later by Dunlop, at Paramatta. Observed till the middle of April.

1835. (I.) Detected by Boguslawski, at Breslau, on the 20th of April. The best elements are those of W. Bessel, son of the great astronomer.

1835. (II.) *The Comet of Encke.* Found July 22nd, by Kreil, at Milan, and observed also by Boguslawski, on the 30th. It was seen by Maclear at the Cape of Good Hope, from September 14th to 24th, with a telescope of Sir W. Herschel's; but no observations could be made.

1835. (III.) The famous *Comet of Halley.* Discovered at the observatory of the Collegio Romano, at Rome, by the director, Dumouchel, on the 5th of August, but not generally found until the 21st or 22nd. It was last seen in Europe by Lamont, on the 17th of May, 1836; having been observed at nearly all the astronomical stations in the world. The elements of Westphalen are founded upon the fine series of observations taken by Bessel at Königsberg, Struve at Dorpat, and by Herschel and Maclear at the Cape of Good Hope.

1838. *The Comet of Encke.* Observed by Galle, at Berlin, on September 16th, and followed until the end of November. About the 7th of the latter month it was just perceptible to the naked eye.

1840. (I.) Discovered by Galle, at Berlin, on December

2nd, 1839, in the constellation Virgo, and observed till February 8th. The comet exhibited a short tail, and was rather bright in the telescope towards the end of the year. The calculations of Peters and O. Struve assign a hyperbolic orbit; but the observations are well represented by a parabola.

1840. (II.) Discovered by the same astronomer on the 25th of January. It was much fainter than the first comet of this year. The elaborate computations of Loomis and Plantamour prove that the period must extend to many centuries. Loomis makes it about 2423 years, and he finds the ellipse far preferable to the parabola.

1840. (III.) A third comet, also discovered by Galle, at Berlin, on the 6th of March, on the confines of Pegasus and Cygnus; the last observation dates three weeks later, and was taken at Pulkowa. The elements resemble those deduced by Burckhardt from Chinese observations of the comet of 1097. It is possible that the same body may have appeared in 1097 and 1840.

1840. (IV.) Discovered at Berlin by Bremicker, on the 27th of October, 1840, in the constellation Draco. It was always faint, and invisible without the telescope; the observations extend to the middle of February, 1841. Götze has shown that the orbit is certainly elliptical, and the period which agrees best with the whole course of observations is 344 years, subject to an uncertainty of about eight years.

1842. (I.) *The Comet of Encke.* Found by Galle, at Berlin, on the 8th of February, and observed last in America, on April 11th. It appeared as a round

bright planetary disc, the nebulosity being doubtless hid in the strong evening twilight.

1842. (II.) Discovered at Paris, by Laugier, on the 28th of October, in Draco, and observed until the end of November. It was always small and faint.

1843. (I.) The Great Comet of 1843, the finest of the present century. Seen near the sun's limb on the 28th of February in America, Italy, and off the Cape of Good Hope; and throughout the southern hemisphere during the early part of March. It became visible in Europe about the middle of this month, and was last seen near the west horizon, at Berlin, on the 15th of April. The orbit is remarkable for its small perihelion distance. The period in Hubbard's ellipse is 376 years.

1843. (II.) Discovered at Paris by Mauvais, on the 3rd of May, on the borders of the constellations Pegasus and Cygnus, and observed till the beginning of October. The calculations of Götze assign a hyperbolic orbit, but the parabola suffices for the accurate representation of the observed path.

1843. (III.) Discovered by Faye, at Paris, on the 22nd of November, in Orion, and last seen at Pulkowa, with the grand telescope of the observatory, on April 10th, 1844. This remarkable comet is found to revolve in an elliptic orbit, slightly inclined to the ecliptic, in about 2718 days: it was again in perihelion on April 3rd, 1851. Le Verrier's elements depend on all the observations deserving of confidence. Professor Challis re-discovered this comet in November, 1850.

1844. (I.) Discovered by De Vico, at the Collegio Romano, on the 22nd of August, and observed till the end of the year. This comet is also found to be perio-

dical, its revolution extending to 1993 days. The return in 1850 was not observed, owing to the comet's unfavourable position in the heavens.

1844. (II.) Discovered at Paris, by Mauvais, on July 7th, and at Berlin, by D'Arrest, on the 9th. It was observed until the 10th of March, 1845. Professor Plantamour has rigorously investigated the elements, and finds a revolution considerably over 100,000 years! or the orbit is not sensibly different from a parabola. This result is the more important in the present case, because the comet was observed at a considerable distance on each side of the perihelion.

1844. (III.) Seen at the Cape of Good Hope on the 18th of December, and on the following night in New South Wales. It was conspicuous in the southern hemisphere for the three weeks following this date, and at the beginning of February was observed in Europe. The last observation was made on the 12th of March, 1825.

1845. (I.) Discovered on the 28th of December, 1844, by D'Arrest, in the constellation Cygnus, and observed till the end of March. It came pretty near the earth, but was not visible without the telescope. The orbit appears nearly parabolic.

1845. (II.) Discovered by De Vico, at Rome, on the 25th of February, and on March 6th, by Faye, at Paris: observed till the latter end of April. It was small, and invisible to the naked eye.

1845. (III.) Discovered at Parma, by Colla, on the 2nd ot June, and very distinct to the unassisted eye for a fortnight subsequently. It exhibited a tail about $2\frac{1}{2}°$ long, and divided by a dark line into two branches. The identity of this comet with that of

1596 appears probable, and D'Arrest's orbit is calculated on this supposition.

1845. (IV.) *The Comet of Encke*, which was so unfavourably situated in the morning twilight that only three observers succeeded in finding it: De Vico saw it at Rome, and it was also observed at Philadelphia and Washington.

1846. (I.) Discovered by De Vico at Rome, on the 24th of January, in Eridanus, and observed by Argelander till May 1st. The best elements are those of Jelinek, who finds an elliptical orbit with a period of revolution extending to 2721 years: this is the most probable period, but the observations leave it uncertain between 2319 and 3255 years. The comet was in perihelion two days before the discovery.

1846. (II.) *The Comet of Biela.* Found on the 28th of November at Berlin and Rome, and observed till the end of April, 1846. For an account of the extraordinary phenomena exhibited by the comet at this appearance, see Chapter VI.

1846. (III.) A remarkable periodical comet discovered by Brorsen at Kiel, in Denmark, on February 26th, in the constellation Pisces. It was observed till April 22nd. The elements were soon ascertained to be elliptical, independent calculations by Brünnow, Goujon, and the author, agreeing as to the short period of revolution, which is about 5½ years. The comet was not seen in the autumn of 1851, when it must have returned to perihelion, owing probably to its faintness in the morning twilight.

1846. (IV.) Discovered by De Vico, on February 28th, in Cetus, and by Bond at Cambridge, U.S., on the 26th; observed till the beginning of May. This

comet is also periodic, the revolution extending to 72 or 73 years, according to Van Deinse and Peirce.

1846. (v.) Discovered on the 29th of July by De Vico at Rome, and two hours later by the author in London. It was observed at Bonn till the 18th of October; was always small and faint, and appeared to move in an orbit differing in no sensible degree from a parabola. Argelander's elements are very exact.

1846. (vi.) Discovered at Naples by Peters on the 26th of June, and observed there till July 21st. De Vico was the only astronomer, besides the discoverer, who was fortunate enough to find this comet. The calculations of Peters and D'Arrest agree in assigning a short period of revolution. According to the former astronomer, whose investigation is somewhat more complete, the period given by the observations is 12·8 years; but is uncertain to the extent of about one year.

1846. (vii.) Discovered by Brorsen, on the 30th of April, and on the following day by Wichmann, at Königsberg. It was pretty conspicuous about the middle of May, and was observed at Leyden till June 12th. Wichmann considered the periodic time about 401 years, while Oudemanns makes it 500 years.

1846. (viii.) Discovered by De Vico, on September 23rd, in Ursa Major, and observed about the middle of October at Königsberg. A parabola satisfies the few observations that were taken of this comet very well.

1847. (i.) Discovered in London, by the author, on the 6th of February, in the constellation Cepheus, and

observed before the perihelion passage till March 24th, when it was bright enough to be visible in the strong morning twilight. Also observed at *noon-day*, close to the sun, on March 30th, and after the perihelion passage till the 24th of April, at Berlin and Markree. The elements are probably elliptical to a very sensible degree, but as no thorough investigation has yet been undertaken, we cannot give any fair approximation to the period; still it may be safely stated at several centuries.

1847. (II.) Discovered by Colla, at Parma, on May 7th, and observed till the end of the year. It was always very faint, and invisible without a good telescope. The orbit is remarkable for the great perihelion distance.

1847. (III.) Detected at Moscow, by Schweizer, in the constellation Cassiopea, on the 31st of August, and observed with the great telescope at Pulkowa till the 28th of November. O. Struve calculated an elliptic orbit, but the parabola of Schweizer represents the observations much more satisfactorily.

1847. (IV.) Discovered by Mauvais, at Paris, on July 4th, on the borders of Cepheus and Ursa Minor, and observed with powerful instruments until the middle of April, 1848. The observations throughout this long interval afford no indications of ellipticity. This comet was in perihelion very nearly at the same time as that found by Schweizer, but as the best orbits give a slight priority to the latter, we have termed it the *third* comet of 1847, though discovered after Mauvais'.

1847. (V.) Found by Brorsen, July 20th, at Altona, in Aries, or on the confines of Aries and Triangulum,

and observed by Rümker till September 12th. Several astronomers determined elliptical elements, and D'Arrest, from the whole series of observations, found the periodic time about 75 years.

1847. (VI.) Discovered by Miss Maria Mitchel, at Nantucket, United States, near the north pole of the heavens, on October 1st; by De Vico, at Rome, on the 3rd; by the Rev. W. R. Dawes, at Cranbrook, Kent, on the 7th; and by Madame Rümker, at Hamburg, on the 11th. It was visible to the naked eye as a hazy-looking star, and in the telescope presented a large mass of nebulous matter without nucleus, but accompanied by a short tail. The comet was last seen at Königsberg, by Wichmann, on January 3rd, 1848. The orbit is not sensibly different from a parabola.

1848. (I.) Discovered by Petersen, at Altona, on August 7th, in Auriga, and observed till the 25th of the same month.

1848. (II.) A return of the *Comet of Encke*, which was observed from August 27th till the end of November.

1849. (I.) Also discovered by Petersen, on October 26th, 1848, in the constellation Draco, but the perihelion passage did not take place till 1849, so that, according to our plan of arrangement, the comet belongs to the latter year. It was observed at Geneva by Plantamour, until the 26th of January, 1849. The observations are very closely represented by a parabolic curve.

1849. (II.) Discovered by Goujon, at Paris, on April 15th, in the constellation Crater, and observed at Liverpool and Berlin until the 22nd of September.

There are no indications of ellipticity, Weyer's parabolic elements agreeing well with the whole of the observations.

1849. (III.) Discovered by Schweizer on April 11th, in Corona Borealis, and a few hours later by Bond, at Cambridge, United States; also at Markree, by Graham, on the 14th. Observed last before the perihelion, by Valz, at Marseilles, on May 9th; detected again by Bond, on August 24th. D'Arrest finds an elliptical orbit, with a period of 8375 years; hence it is certain that the third comet of 1849 cannot be identical with the second of 1748, as was at first conjectured.

1850. (I.) Discovered at Altona, by Petersen, on May 1st, nearly in the position in which the same astronomer detected the first comet of 1849. It became very distinct to the naked eye early in July, exhibiting a bright nucleus and a tail several degrees in length. D'Arrest's elements, which are parabolic, satisfy all the observations before the perihelion passage with considerable accuracy.

1850. (II.) Discovered by Mr. G. P. Bond, at Cambridge, United States, on the 29th of August, and about a week later by Brorsen, at Senftenberg, and other European observers; it was never very bright.

1851. (I.) The first appearance of the *Comet of Faye* since the discovery of its periodicity in 1843. At this apparition it was always extremely faint, and quite beyond the power of any but the very largest telescopes in existence. Professor Challis found it with the Northumberland equatorial, at Cambridge.

1851. (II.) Discovered by D'Arrest, at Leipzic, on the

27th of June, and soon ascertained to be periodical (see Chapter VII). It remained visible till the beginning of October, but was always very small and faint.

1851. (III.) Found by Brorsen, at Senftenberg, on the 1st of August, and observed till November. The observations indicate no sensible deviation from a parabolic orbit.

1851. (IV.) Also discovered by Brorsen, on October 22nd, and then pretty bright, with a double tail—the shorter branch turned towards the sun. It became rapidly fainter.

1852. (I.) A reappearance of *Encke's Comet*, which was first observed at Mr. Bishop's private observatory, Regent's Park, London, on the 9th of January; observations were continued until March.

1852. (II.) Detected by Chacornac, at Marseilles, May 15th, and by Petersen, at Altona, on May 17th, when it was very small and faint. It subsequently passed near the north pole of the heavens. The elements will be approximate only.

1852. (III.) Found by Westphal, at Göttingen, on June 27th, and subsequently by Peters, at Constantinople. The orbit is an ellipse, with a period of about 70 years.

ERRATUM.

Page 43, for *November* 12 *that*, read *November* 12*th at*.

INDEX.

N.B.—The Notes to the Catalogue of Orbits, being arranged in the *chronological order* of the Comets, are not included in the following Index.

THE END.

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